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THE LIFE

OF

JAMES WATT,

WITH

SELECTIONS FROM HIS CORRESPONDENCE.

PUBLIC LIBRARY

BY

JAMES PATRICK MUIRHEAD, M. A.,

AUTHOR OF 'THE ORIGIN AND PROGRESS OF THE MECHANICAL INVENTIONS OF WATT;'
CORRESPONDENCE ON THE DISCOVERY OF THE COMPOSITION OF WATER,' ETC.

ILLUSTRATED WITH WOODCUTS.

NEW YORK:
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1859.

PREFACE.

The present volume may, it is hoped, supply a want which has long been felt; that, viz., of a full, yet compendious and authentic biography of James Watt. In a recent work,* prepared by the author from the MSS. of the great engineer preserved by his son, as well as from others, of no less value, in the possession of Mr. Boulton, there were comprised, (1.) a Biographical Memoir of Mr. Watt; (2.) a Selection from his Correspondence; and (3.) the Specifications of all of his Patents. The favour with which that work was received by the press and the public is gratefully acknowledged. The long series, however, of large copper-plate engravings of machinery by which it was illustrated,—(thirty-four in number, delineating no fewer than sixty-eight separate figures,)—necessarily raised its cost above the means of many who might otherwise have desired to possess it; while the minute descriptions contained in the specifications of patents, and their relative drawings, are of course more desirable for the use of the scientific engineer and the mechanical philosopher, than of the general reader.

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* 'The Origin and Progress of the Mechanical Inventions of James Watt.' 3 vols. 8vo. and 4to. London: John Murray, 1854.

The author has now, therefore, ventured to remodel, and to reproduce in a form at once more comprehensive, more convenient, and less costly, the Biographical Memoir above referred to. A few unimportant pages have been omitted; many of the most interesting passages from the correspondence of the great engineer have been incorporated; and other large additions, from various sources, have been made,—a considerable portion of the new matter relating to Mr. Watt's family and private history; while the principle has been adhered to, of allowing his inventions and discoveries to be explained, as far as possible, in his own plain, clear, and forcible language.

Of the immense results of those inventions, and their present and future value to the world, it is already difficult to form any adequate conception. But some faint idea of their magnitude may be gathered from such facts as these:—that less than a single century ago, only a few clumsy and imperfect "fire-engines," of the old atmospheric sort, were employed in pumping water out of some widely scattered coal-pits and mines; that they did their task laboriously, expensively, and badly; that steam was not then applied directly, nor, as then used, was it capable of being applied with advantage, either to manufactures, to processes in the Useful Arts, to Navigation, to Land Transport, to War, or to Agriculture;—and that now, the united steam power of Great Britain alone, employed in all of those different ways, (every engine having been constructed since the improvements of Watt were first made known,) is estimated as *equivalent to the manual* *labour of upwards of four hundred millions of men, or more than double the number of males supposed to inhabit the globe.** How startling are such statistics;—how eloquently is the panegyric of the inventor thus expressed by the stupendous works of his genius!

As a kinsman of the illustrious engineer,—as long the intimate friend and now one of the executors of his son,—and as the son-in-law of the late Mr. Boulton, the author has enjoyed the peculiar privilege of unrestrained access to the stores of original documents, as well as of anecdotes, by which this volume has been enriched. This circumstance may be a sufficient guarantee of the genuineness and interesting nature of the materials from which he has had to select; and the care bestowed in moulding them to their present form will be well repaid, if it secures a complete and accurate history of the life of one whom the common consent of mankind has now placed "at the head of all inventors, in all ages and nations."

The checkered career of so great a man,—now dark with shadows, now bright with lights,—may well teach the stern truth,—

"That life is not as idle ore,

But iron dug from central gloom,
  And heated hot with burning fears,
  And dipp'd in baths of hissing tears,
And batter'd with the shocks of doom

To shape and use:" †—

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* 'Quarterly Review,' vol. civ. p. 411. 1858.

† Tennyson, 'In Memoriam,' § cxvi.

yet it is full of hope and encouragement to those who read its lessons aright. For it sets forth the dignity of that intellectual pre-eminence, which crowns perseverance in honourable toil;—the lustre of that nobility of soul, which finds its highest scope even amid humble pursuits;—the majesty of that wisdom, which intently, tranquilly, and reverently searches out the mysterious works and ways of Creation.

> "Fame is no plant that grows on mortal soil,
> Nor in the glistering foil
> Set off to the world, nor in broad rumour lies;
> But lives and spreads aloft by those pure eyes
> And perfect witness of all-judging Jove;
> As He pronounces lastly on each deed,
> Of so much fame in Heaven expect thy meed." *

* Milton, 'Lycidas,' l. 78–84.

PUBLISHERS' NOTE.

The Publishers have omitted portions of the original English edition which appeared unimportant and uninteresting to the American reader.

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LIFE OF WATT.

CHAPTER I.

INTRODUCTION—INVENTORS AND THEIR HISTORY—LINEAGE OF JAMES WATT—HIS GREAT-GRANDFATHER—HIS GRANDFATHER THOMAS WATT—BURGH OF CRAWFORDSDYKE—BURGH OF GREENOCK—LIFE AND PURSUITS OF THOMAS WATT—HIS MARRIAGE—AND DEATH.

THE fame of James Watt, great as it unquestionably became in the course of his long and honoured life, has increased since his death in a degree that may, perhaps, be termed unprecedented, being co-ordinate with nothing less than the unlimited development of his own manifold inventions.

The respect which in all ages and countries has ever been paid to inventors seems, indeed, to rest on something more profound than mere gratitude for the benefits which they have been the means of conferring on mankind; and to imply, if it does not express, a consciousness that by the grand and original conceptions of their minds they approach somewhat more nearly than their fellows to the qualities and pre-eminence of a higher order of being. "The dignity," says Lord Bacon, "of this end of endowment of man's life with new commodity appeareth by the estimation that antiquity made of such as guided thereunto; for whereas founders of states, lawgivers, extirpators of tyrants, fathers of the people, were honoured but with the titles of demigods, inventors were ever consecrated among the gods themselves." * Of all the inventions which the ingenuity of man has

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* Fragments of Valerius Terminus, on the Interpretation of Nature; Works of Bacon, by Basil Montagu, 1825, vol. i., p. 266.

devised, that of the modern steam-engine is, whether we regard its own mechanism and mode of performing its operations, or the operations themselves, perhaps the most wonderful, and certainly the most useful. "We must confess," says Belidor, "that this is the most marvellous of all machines, and that there are none of which the mechanism has so much analogy to that of animals. Heat is the principle of its motion; in its different pipes there takes place a circulation like that of the blood in the veins, having valves which open and shut themselves at right times; it feeds itself, performs its evacuations at regular intervals, and draws from its own work all that is needful for its subsistence." * So, Wordsworth and Coleridge, when on a tour in Scotland, "passed," says Dr. Wordsworth, "a steam-engine, and Wordsworth made some observation to the effect that it was scarcely possible to divest oneself of the impression, on seeing it, that it had life and volition. 'Yes,' replied Coleridge, 'it is a giant with one idea.'" †

In proportion to the estimate which men have formed of the importance of the inventor's work is generally the desire they feel to learn the history of its origin and progress; and of the development of the mind of its contriver. It will be seen from the following pages, that the life of the creator of the modern steam-engine was one, as has been justly remarked, of patriarchal simplicity, "devoted to labor, to study, to meditation;" and that in a humble condition, and a career of virtuous industry and patient thought, "projects were elaborated, which were destined to raise the British nation to an unheard-of height of power."

The first of the paternal ancestors of James Watt, of whom any notices have been preserved, is his great-grandfather; the minute details of whose personal history, however, have shared nearly the same oblivion in which even his Christian name is sunk. It is only known, from the traditions of his family, that he lived in Aberdeenshire in the earlier half of the seventeenth century, and followed the business of a farmer, whether of his

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* Belidor, Archit. Hydraul., vol. ii., pp. 324, 325, ed. 1739.

† Life of Wordsworth, vol. ii., pp. 447, 448, ed. 1851.

own land or not we can only conjecture; that his peaceful pursuits did not exempt him, in "the troubles" of that period, from a rude summons to arms, and an early death in battle; that he perished in one of the wars of Montrose, fighting, in all likelihood, for the cause of the Covenant; that his property was confiscated; and that his orphan son, Thomas, was educated by the care of some distant relations.

Thomas was born, according to one account, in 1639, according to another in 1642, and was at all events soon removed from Aberdeenshire.

He settled, early in life, in the little burgh of barony of Crawfordsdyke, or Cartsdyke, situated in the barony of Cartsburn, in the close vicinity of the town of Greenock in Renfrewshire. He was a "teacher of navigation;" or, as he is styled on his tombstone, "Professor of the Mathematicks;" a vocation for the exercise of which it appears that neither Cartsdyke nor Greenock could, previous to that time, have afforded any very wide scope. Even so late as April 1700, in an enquiry for settling the amount of taxation to be made in respect of their trade, it was given in evidence that the whole shipping of the two burghs together consisted of but one ship belonging wholly to Greenock; three ships having part-owners in Glasgow; and two barks and a traveller-boat, said to belong to Greenock. In this estimate there can be no doubt that the open or half-decked boats employed in the herring or other fisheries were not included.

The population of Crawfordsdyke and of Greenock must, at the time of Thomas Watt's settlement there, have been small; for we learn that nearly a century later it amounted to no more than four thousand one hundred souls in the whole parish. We may reasonably wonder at any teacher of mathematics whose practice was limited to so narrow a field, being able to derive even a sufficient subsistence from his erudite labours. Yet not only did he maintain himself and his family, in respectability and comfort, on the limited earnings of such humble but honourable toil, but he also accumulated funds sufficient to enable him to purchase the house in Crawfordsdyke in which he lived, with a garden attached, and afterwards a house in Greenock.

He seems to have been highly esteemed among his worthy brother-citizens of the burgh; over which he was made chief magistrate, or "Baillie of the Barony;" he also became an Elder of the Parish and Presbytery, as well as Treasurer and Clerk to the Kirk-Session, ecclesiastical dignities which must be supposed to bear witness to the integrity of his life; and proofs remain of the nature of his dealings with men and things in each of those capacities, which demonstrate the rigidity of the rule he maintained over the minds and morals of the little community. Repairing the church,—widening the bridge,—trying by mathematical standards the weights and measures used in the burgh,—are associated, in the records of the court in which he presided, with his infliction of penalties for assault and battery of the lieges, his threatening with "the pain of fourtie shillings Scots, *toties quoties*," "several of the young ones who does upon that night called Hallowin night abuse several yards in drawing of kail," his statuting and ordaining that "in all time comeing, if any persons keip hens, and they doe prejudice to any neighbour, that the owner sall mak up the damnage attour lyable in fourtie shilling *toties quoties*. This act extends to all sorts of taim foules;" and many other instances of discipline, equally minute, equally solemn, and, doubtless, equally salutary. "Sitting in and haunting taverns, on Friday and Saturday nights," was, under the reign of his exemplary censorship, to be "abstained from after nine of the clock, at which time the bell of the kirk is allowed to be rung, to give advertisement to all to repair to their own house, except in case of necessity;"—offending skippers were made "to acknowledge their guilt" in "loosing their ships and taking them to seaward on the Sabbath Day," and were then held to be cheaply let off by being "censured with a sessional rebuke, and admonished to carry more tenderly on the Lord's Day for the future."

But the greatest eruption of the volcano of vice which then threatened to overwhelm Carsdyke, with its torrent of moral lava, probably occurred when "the Minister informed the Session that mountebanks having come to the place, had erected a stage for a stage-play to be acted thereon, and proposed"—(*i. e.* the Minister,—not the mountebanks!)—"they should fall on some effectual method for suppressing the same." And "the Session, considering the thing to be unlawful, and inductive of much sin and looseness, appointed some of their number, to wit, James Crawford, John Clark, and Thomas Watt, to go to the Doctor (not the minister but the quack-mountebank), in name of the session, and discharge him to use rope-dancing, and men simulating themselves fools, or women exposing themselves to public [gaze] by dancing on the stage, or any indecent behaviour, allowing him only to expose his drugs or medicines to public sale."

The name of Thomas Watt's wife was Margaret Sherrer; by her he had six children, of whom Margaret, Catherine, and Thomas, all died in infancy, and Doritie,—so the name is spelt,—at the age of eighteen. Thomas Watt died on the 27th of February, 1734, "aged about 95 years," and his widow on the 21st of March, 1735, "aged 84 years," as stated in the Register of burials of the Old or West parish of Greenock; or 92 and 79 years respectively, as engraved on the tomb-stone of Thomas Watt and his family, in the church-yard of the same parish.

CHAPTER II.

JOHN AND JAMES WATT OF GREENOCK—SCENERY OF THE FRITH OF CLYDE—RAPID PROGRESS IN THE NAVIGATION OF THAT RIVER—LIFE AND PURSUITS OF JAMES WATT OF GREENOCK, FATHER OF THE GREAT ENGINEER—AGNES MUIRHEID, HIS WIFE—MUIRHEADS OF LACHOP—FLODDEN FIELD—CHARACTER AND DEATH OF AGNES MUIRHEAD OR WATT—HER BROTHER, JOHN MUIRHEID.

Two sons of Thomas Watt, John and James, grew up to man's estate, surviving their parents; and both of them appear to have been diligently trained by their father in his own pursuits; in which John, the elder of the two, was for some time able to be of service in assisting his kind instructor. In 1712, John Watt, being then twenty-five years of age, was appointed clerk to the barony of Cartsburn, and burgh and barony of Crawfordsdyke, of which his father was for many years the baillie. But he soon quitted Greenock for Glasgow, to seek a wider field for the exercise of his profession, and there, as a surveyor, he obtained considerable practice, dying unmarried at the age of fifty, in 1737. He left behind him a Survey of the course and Frith of the river Clyde, from above Rutherglen and Dalbeth on the East, to Loch Ryan, Portincross, and the coast of Ireland on the South, and the islands of Islay, Colonsay, and part of Mull, on the West. This Survey was made in 1734; it was engraved in 1759, and published in 1759–'60, by the united cares of his brother James, and of his two nephews, John and James; of whom the one perished at sea two years afterwards, on a voyage to America in one of his father's ships, at the age of twenty-four, and the other was the great engineer.

"The Survey," writes the latter in 1794, "as far as the

Point of Toward, was done by my uncle before I was born; the remainder was added by my father and my brother, but is not over accurate." Several alterations were made on the map, by the engineer's own hand, before it was engraved, particularly on that portion of it comprehending the islands of Mull, Islay, &c., which occupies a separate division of the map, and is entitled, "Entry to the River and Firth of Clyde and adjacent islands, according to the best authorities."

James, the younger son of Thomas Watt, was born on the 28th of January, 1699, and it is said, after having served an apprenticeship to a builder and shipwright in Crawfordsdyke, to have settled in Greenock about the time of his marriage, in 1728 or 1729, when, consequently, he must have been on the verge of thirty years of age. If not so deeply versed in the theories of abstract science as either his father or his brother,—or, we need scarcely add, as his illustrious son,—he seems to have been not less energetic in the practice of those useful occupations to which he devoted his life. They were, in his case, a somewhat multifarious compound of commerce and of the more ordinary handicraft arts required for the purposes of commercial and seafaring men; he was a shipwright; a ship-chandler, supplying vessels with nautical apparatus, stores and instruments; a builder, and a merchant. For upwards of twenty years he was a member of the Town Council of Greenock, and, during great part of that time, its Treasurer; a magistrate, and always a zealous and enlightened promoter of the improvements of the town of which he was an inhabitant.

The lady whom James Watt of Greenock married was Agnes Muirheid, or Muirhead (for the name was indifferently spelt in either way), "a fine-looking woman, with pleasing, graceful manners, a cultivated mind, an excellent understanding, and an equal, cheerful temper." She was descended from a branch of a family of some note in the early history of Scotland, "settled in the shire of Clidesdale time immemorial, and certainly before the reign of David the first of Scotland, anno 1122." The ancient family of the Muirheads of Lachop who were chiefs of their clan, gave to the see of Glasgow, in 1454 (before its erection into an archbishopric), its pious and learned Bishop Dr. Andrew Muirhead, who in 1468 was sent as Ambassador to Copenhagen, to settle the marriage of Margaret "the Maid of Norway" to King James III.; and, in 1494, the same family supplied the realm of Scotland with a Lord Clerk Register, Judge, and Secretary of State, in the person of Dr. Richard Muirhead, Dean of Glasgow. But the most glorious, though disastrous fate of the Muirheads, clan and chieftain alike, befel them on the fatal day of Flodden field, where they occupied the post of honour and of danger as the body-guard of the King. There, when, as the old song has it, "The English, *for ance*, by guile wan the day," they sealed their loyal devotion to their monarch with their blood; and Sir Walter Scott, in his "Minstrelsy of the Scottish Border," has preserved the record of their fatal feat of arms in the old ballad of "The Laird of Muirhead."

Agnes Muirheid lived in happy wedlock with James Watt of Greenock for a quarter of a century, and died in 1755, aged 52. Her portrait, which is still in existence, well executed in oil colors, seems to justify the encomiums passed by those who knew her, on the great comeliness of her countenance, and on the quiet good sense and serene composure of her mind. In Mr. Williamson's volume her likeness is thus drawn, and all that we have ever heard concerning her confirms the truth of the portraiture: "A gentlewoman of good understanding and superior endowments, whose excellent management in household affairs would seem to have contributed much to the order of her establishment, as well as the every-day happiness of a cheerful home. She is described as having been a person above common in many respects, of a fine womanly presence, ladylike in appearance, affecting—according to our traditions—in domestic arrangements what it would seem was considered, for the time, rather a superior style of living. . . . Our venerable informant described James Watt's mother—in her eloquent and expressive Doric—as '*a braw*,

braw woman—none now to be seen like her.'" It is said that her death was preceded by a singular dream, in which "she heard a voice requiring her to prepare for appearing within three days before the judgment-seat of CHRIST;" and that within three days thereafter she suddenly died.*

John Muirheid, the brother of Mrs. Watt, and James Watt, her husband, were united in many mercantile adventures, and although Mr. Watt, in the latter part of his life, experienced heavy commercial losses, which swept away a great portion of the respectable fortune which his assiduous industry had realized; we believe those to have arisen from enterprises with which no member of his brother-in-law's family was in anywise associated.

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* Memorials of Watt, p. 154.

CHAPTER III.

CHILDREN OF JAMES WATT OF GREENOCK, AND AGNES MUIRHEID—BIRTH OF JAMES WATT—JOHN WATT, HIS YOUNGER BROTHER—JAMES WATT'S CHILDHOOD—HIS HOME, EDUCATION, AND FEEBLE HEALTH—MRS. CAMPBELL'S MEMORANDA OF HIS EARLY YEARS—HIS POWERS OF IMAGINATION—HIS FIRST OBSERVATION OF THE CONDENSATION OF STEAM—VARIETY OF HIS YOUTHFUL STUDIES AND PURSUITS.

To Mr. Watt, of Greenock, and Agnes his wife, there were born five children, of whom the three eldest—two sons and a daughter—died in infancy or early childhood. The fourth was James, the subject of this biography, who was born on the 19th day of January, 1736; and the fifth was John, who was born in 1739, and died at sea, as has already been mentioned, in 1762. He had been destined to follow his father's business, and the fatal voyage to America, on which he was sent while still so young, was probably considered as likely to prove highly advantageous, by increasing his experience of nautical affairs, and enlarging the horizon of his observation, and it is curious to observe how decidedly a turn for scientific pursuits seems, in some measure at least, to have been common to every male of that family, so as to have become almost the birthright of both of the grandsons of Thomas Watt, "the old mathematician." And it may be added that the same inclination continued to "run in their veins," till the line of direct male descent itself became extinct, by the death, without issue, of both of the sons of the illustrious improver of the steam-engine.

The childhood of James Watt presents us with the spectacle, only too frequent in the histories of men of genius, of great delicacy of constitution, and consequent inability to bear an equal part in either the toils or the sports common to other boys of his own age. But the same excellent authority on which we know that in his early years he was physically sickly and feeble, has also told us that:—"When he was six years of age, a gentleman calling on Mr. Watt observed the child bending over a marble hearth with a piece of coloured chalk in his hand. 'Mr. Watt,' said he, 'you ought to send that boy to a public school, and not allow him to trifle away his time at home.' 'Look how my child is occupied, before you condemn him,' replied the father. The gentleman then observed, that the child had drawn mathematical lines and circles on the marble hearth, and was then marking in letters and figures the result of some calculation he was carrying on; he put various questions to the boy, and was astonished and gratified with the mixture of intelligence, quickness, and simplicity, displayed in his answers. 'Forgive me, Mr. Watt;—this boy's education has not been neglected:—he is no common child.'"

"His parents were indulgent, yet judicious in their kindness; and their child was docile, grateful, and affectionate. From an early age, he was remarkable for manly spirit, a retentive memory, and strict adherence to truth; he might be wilful or wayward, but never was insincere. His faults were ever acknowledged with candour, and, when any quarrels occurred with his young friends, his father said, 'Let James speak; from him I always hear truth.'"

"He received from his mother his first lessons in reading; his father taught him writing and arithmetic. Owing to variable health, his attendance on public classes at Greenock was irregular; his parents were proud of his talents, and encouraged him to prosecute his studies at home. His father gave him a set of small carpenter's tools, and one of James's favourite amusements was to take his little toys to pieces, reconstruct them, and invent new playthings." Every one must admire the enlightened affection which could, amid all the happy little works and ways of home, allow to the intelligent boy a latitude such as, in those days of rigid paternal discipline, was perhaps unusual, but not misplaced; which could with watchful kindness supply every reasonable wish and want, suggest every cheerful and thoughtful occupation, and yet refrain from urging, in hours of illness or languor, the opening mind to more sustained exertions, thus avoiding all risk of overstraining its energies, and of weakening its powers.

Of the boyish years of the future mighty engineer, various incidents have been recorded,—some of them slight and trivial enough, such as are those of the little respect in which his school companions are said to have held his abstracted and contemplative nature, his silent sufferings as an invalid, and his consequent disinclination—and, indeed, inability—to mix in boisterous play and unmeaning idleness; as well as of the slowness with which most of them awoke to the conviction that "Jamie Watt" was "no vulgar boy," and was likely to prove no illiterate one. The report, however, of "a certain mental dulness" said to have been "exhibited by him during the earlier period of his school days," rests only on the opinion, conceived at that early age by one or two of those very comrades,—"burly youngsters," as they have been appropriately termed;—and naturally leads us to remark that it appears to be rather inconsistent with that other record which we have just been transcribing.

Fortunately it happens that other anecdotes have also been preserved, relating to the same early period, which are of great value in every way, and far too curious to be here omitted. Their tendency is uniform, and in one direction; while the authenticity of the MS. notice from which they are taken is unimpeachable, and its exactness has been effectually guaranteed. The document in question is entitled, "Memoranda of the early years of Mr. Watt, by his cousin, Mrs. Marion Campbell (born Muirheid, daughter of his mother's brother), who was his companion in early youth, and friend through life; dictated to and written down by her daughter, Miss Jane Campbell, in 1798." In thanking Miss Campbell in 1834 for a transcript of that paper the late Mr. Watt of Aston Hall (son of the great engineer), assured her that he attributed the greatest value to a record which he justly described as containing information at once so full and so specific; and remarked that it was so accordant with all he had himself known of his revered father's character in later years, that he entertained not a doubt of its perfect accuracy.

"That his powers of imagination and composition," says Mrs. Campbell, "were early displayed, appears from the following incident. He was not fourteen when his mother brought him to Glasgow to visit a friend; his brother John accompanied them: on Mrs. Watt's return to Glasgow some weeks after, her friend said, 'You must take your son James home; I cannot stand the state of excitement he keeps me in; I am worn out with want of sleep; every evening before ten o'clock, our usual hour of retiring to rest, he contrives to engage me in conversation, then begins some striking tale, and, whether humorous or pathetic, the interest is so overpowering, that all the family listen to him with breathless attention; hour after hour strikes unheeded; in vain his brother John scolds and pulls him by the arm, Come to bed, James; you are inventing story after story to keep us up with you till after midnight, because you love company, and your severe fits of toothache prevent your sleeping at an earlier hour.'

"Sitting one evening with his aunt Mrs. Muirheid at the tea-table, she said: 'James Watt, I never saw such an idle boy: take a book or employ yourself usefully; for the last hour you have not spoken one word, but taken off the lid of that kettle and put it on again, holding now a cup and now a silver spoon over the steam, watching how it rises from the spout, and catching and connecting the drops of hot water it falls into. Are you not ashamed of spending your time in this way?'"

"In the year 1750," said M. Arago, in addressing the assembled members of the Institute of France, "each one of us, in the same situation as Mrs. Muirheid, would perhaps have used the same language. But the world has made a stride, and our knowledge has grown greater; and so, when I shall immediately explain to you that the principal discovery of our fellow-member was a particular mode of converting steam into water," [the condensation of steam in a separate vessel from the boiler], "Mrs. Muirheid's reproof will present itself to our minds under a totally different aspect: the little James before the tea-kettle becomes the mighty engineer preluding to the discoveries which were to immortalise him; and it will, by every one, undoubtedly be deemed worthy of remark, that the words CONDENSATION OF STEAM should naturally have come to find a place in the history of Watt's early childhood."

Mrs. Campbell's narrative continues:—"It appears that when thus blamed for idleness, his active mind was employed in investigating the properties of steam: he was then fifteen, and once in conversation he informed me that before he was that age he had read twice, with great attention, S'Gravesande's Elements of Natural Philosophy;* adding that it was the first book upon that subject put into his hands, and that he still thought it one of the best. When health permitted, his young ardent mind was constantly occupied, not with one but with many pursuits. Every new acquisition in science, languages, or general literature, seemed made without an effort. While under his father's roof, he went on with various chemical experiments, repeating them again and again until satisfied of their accuracy from his own observations. He had made for himself a small electrical machine, and sometimes startled his young friends by giving them sudden shocks from it."

We pause here to remark that in point of novelty, and, indeed, also of mental capacity, required to apprehend its true nature and construction, an electrical machine was in those days a very different thing from one made or used at the present time. For young Watt's performance must have been about the years 1750–53; and, as many of our readers are aware, the Leyden phial was not invented till the years 1745–46.†

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* 'Physices Elementa Mathematica. Auctore Gulielmo Jacobo's Gravesande.'

† See Priestley's History of Electricity, p. 80, ed. 1769.

"His early years were passed in Greenock; from the age of fourteen he was often in Glasgow with his uncle Mr. Muirheid, and read and studied much on chemistry and anatomy. He took a deep interest in this latter subject, and in all connected with the medical art, and was once observed carrying off a child's head that had died of some uncommon complaint." Mr. Watt continued through life much attached to the medical art, and had deeply studied his own constitution. He treated his own complaints, and those of his family and friends, *secundum artem;* and told his son that had he been able to bear the sight of the sufferings of patients, he would have been a surgeon.

"Under Mr. Muirheid's roof he met with good society, and formed friendships with several intelligent and well-educated young men; they had frequent evening meetings to give or receive information. These gentlemen acknowledged and appreciated Mr. Watt's superior abilities; his manners were so kind and unassuming that no jealous feelings were ever excited; his warm affections and stern integrity commanded their esteem and regard; yet they sometimes feared while they loved him, as he had no patience for folly, and could be sarcastic.

"The agony he suffered from continued and violent headaches often affected his nervous system, and left him for days—even weeks—languid, depressed, and fanciful; at those times there was a roughness and asperity in his manner that softened with returning health. He often passed the summer months in Mr. Muirheid's family, on the banks of Loch Lomond, near the spot where Buchanan the historian was born, and the celebrated Napier of Merchistoun passed many years of his life. Mr. Watt was partial to the country, and when health permitted, entered with his young companions into its active sports and amusements. Indefatigable in his habits of research and observation, every excursion he took extended his knowledge; not contented with adding to his botanical and mineral treasures, he entered the cottages of the poor to study their characters, and listen for hours to their local traditions, popular ballads, and wild superstitions.

"He enjoyed society in a small select circle; his talents for conversation were always remarkable; he seldom rose early, but accomplished more in a few hours' study than ordinary minds do in many days. He never was in a hurry, and always had leisure to give to his friends, to poetry, romance, and the publications of the day: he read indiscriminately almost every new book he could procure. On a friend entreating him to be more select in his choice, he replied, 'I have never yet read a book, or conversed with a companion, without gaining information, instruction, or amusement.' He was alternately very active, or, apparently, very indolent; and was subject to occasional fits of absence. He had a quick perception of the beauties of nature, and delighted in exploring the wild glens of his native land, and tracing to their source the mountain torrents. Though modest and unpretending, yet, like other great men, he was conscious of his own high talents and superior attainments, and proudly looked forward to their raising him to future fame and honour."

Such, with the exception of a short concluding portion relative to Mr. Watt's married life, which will hereafter be introduced in its proper place, is the whole of Mrs. Campbell's succinct, yet comprehensive narrative. We hope that "the reverence of kindred" does not unduly influence our judgment, when we venture to express a belief that it will always occupy an honourable place among the annals of the childhood and youth of great men. It is not often, indeed, that so forcible a sketch has been drawn of the early character of one afterwards so highly distinguished, by any artist favoured with such frequent opportunities of close observation of her subject, and at the same time, let us add, with so happy a command of her pencil. We feel assured that the portrait she has given us of James Watt in his youth, distinct as are its features, and fresh and lively as are its tints, is neither painted in too glowing colours, nor in any way too highly varnished; and that by all who attentively consider it, it will be admitted to bear on its countenance the stamp of a self-evident fidelity.

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CHAPTER IV.

SCHOOLS AND SCHOOLMASTERS OF JAMES WATT—ANECDOTES OF HIS BOYISH HABITS AND PASTIMES—PORTRAITS OF NAPIER AND NEWTON—HIS CALL TO BE A MECHANICAL PHILOSOPHER—HIS VISIT TO GLASGOW—ACQUAINTANCE WITH PROFESSORS OF THE UNIVERSITY—JOURNEY TO LONDON—PRACTICE OF MATHEMATICAL-INSTRUMENT-MAKING—RETURN TO SCOTLAND.

During the period to which Mrs. Campbell's memoranda chiefly apply, his father s house in Greenock was the head-quarters of young Watt, from which he frequently made such excursions as she has described, to the homes of other kind relations and friends, either during his vacations, or when health rendered change of air and relaxation advisable. The commercial school of a Mr. McAdam he attended, though, as it is said, not very punctually, nor perhaps over diligently; a more than respectable proficiency in Latin, and some knowledge of the elements of Greek, he attained under the tuition of a learned and virtuous person of the name of Robert Arrol, master of the grammar-school of Greenock; mathematics he studied with far greater zest, and with proportionate success, under one John Marr, whose designation is given, in the attestation of some deeds of that date, as "mathematician in Greenock."

During the course of early education which he was thus receiving, the boy is said to have been often known to stand angling from a jetty which ran out into the sea, at the back of his father's house on the shore at Greenock; and which thus offered a tempting opportunity for exercise of the gentle, silent, and solitary art. Such pastime, so invitingly presented to his hours of leisure, he must have been either more or less than a boy altogether to have slighted; and we should have been very willing to credit, upon any tolerably circumstantial authority, the further statement that the same recreation was "often resorted to by him even in after-days, when confinement or over-application to study had rendered a slight or temporary relaxation necessary to his constitution," &c.* But we have no other ground than the general statement above cited, for being able to do so; and there is only too much reason to think that, during by far the greater part of his long and laborious life, Mr. Watt had neither the leisure, nor often the opportunity, nor latterly perhaps the inclination, to amuse himself with that peaceful recreation, to many minds so full of delight, so calmly contemplative, and healthfully active.

However that may have been, there were pursuits which young Watt preferred even to the sports usually most popular with youths of his years. The ill health which at first seemed likely to form an obstacle to his rapid advancement in learning, seems to have had in his case, as in that of many others, only the effect of forming habits of persevering study, and of a disregard of temptations to the indolent loss or frivolous waste of time and thought. "I even think it an advantage to me, and am truly thankful for it," says Dr. Priestley, "that my health received the check that it did when I was young; since a muscular habit from high health, and strong spirits, are not, I think, in general accompanied with that sensibility of mind which is both favourable to piety and to "speculative pursuits."† And to the successful cares of James Watt's homely tuition may in a great part be traced not only his habitual industry, and practice of many other humble virtues, but also that neatness in drawing, handwriting, and other manual occupations, together with skill in the computation of numbers, which he was wont to reckon among his favourite accomplishments; as well as that strong love of order which presided over every arrangement, and bestowed on his conversation and thoughts, in an extraordinary degree, all the excellences of a lucid method.

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* Memorials of Watt, p. 136.

* Memoirs of Dr. Priestley, by himself, p. 103, ed. 1806.

In witnessing his father's mode of conducting his business, and assisting him in several of its details, he appears to have acquired both good habits of commercial and manufacturing diligence, and many useful rudiments of practical mechanics. The carpenter's benches and tools which that business kept in full occupation, were fraught with instruction to a mind that was already decidedly bending itself towards the study of the mechanical arts; and the frequent completion or restoration of the rigging, fittings, and furniture of a ship,—the sails and ropes, the blocks and tackle, the pumps and capstans, the rudder and compasses,—involved the application of many ingenious resources of a rude sort of natural philosophy, which he was not slow to apprehend and treasure up. He soon learned to construct, with his own hands, several of the articles required in the way of his father's trade, thus gaining a ready familiarity in working with the different kinds of metal, wood, and other materials, and a serviceable knowledge of their comparative qualities. He had a small forge set up for his own use; was fond of repairing and making all sorts of instruments; and did not disdain to form out of a large silver coin, and present to a friend, as a trophy of his early skill as a metal-smith, the *Regium Donum* of a silver punch-ladle.

His father made and erected, for the use of "the Virginia tobacco ships," the first crane ever seen or employed at Greenock; and of that, as of many other useful or curious machines—(among their number was *a barrel organ*),—small working models were neatly prepared by the young artificer. Even in his extreme old age there were not wanting occasional recollections of the minor, but secret, mysteries of such handicraft, in which he had been initiated when working, "in his shirt-sleeves," in the carpenter's shop:—as when, in his eightieth year, he instructed a certain great bookseller to have his boxes for books *planed on the inside;* or wrote to Sir Henry Raeburn (2d March, 1816), "I beg to advise your packer always to rub his wood-screws on some candle-grease before he screws them in: it will tend much to his own ease as well as to that of him who unscrews them."

A familiarity with the use and principles of construction of the telescopes, quadrants, and other optical instruments of which his father kept a stock for the supply of ships, was also early acquired by the boy, who always manifested a strong inclination to observe the problems of the physical world around him, and to reflect on their causes. "The prosecution of his favourite geometry," says Mr. Williamson, in introducing another of those interesting local anecdotes which give its peculiar value to his work, "now occupied habitually his thoughts and time; and it is not surprising that astronomy should have become with him a fascinating study. In the repositories of his father were to be found abundance of optical instruments of various kinds, calculated to render his observations of the heavenly bodies both accurate and enlarged. Of these the young astronomer sedulously availed himself. . . . To the south of the town, and on the rising ground behind the church, at no great distance from his father's house, was a clump of trees of considerable extent, composed of stately elms and venerable beeches, part of what were, in former days, the retired and beautiful pleasure-grounds of the Old Mansion-house of Greenock. Here the young recluse found a genial retreat. To this spot he was wont to retire at night as well as by day; and, like another Ferguson, the astronomical herd-boy of Scotland, was known to spend hours lying upon his back, to watch through the trees the wondrous movements of the stars."*

A circumstance which, whether we regard it as merely a curious coincidence, or as having perhaps in some degree exercised a prophetic direction over the future destiny of young Watt, must be considered as certainly remarkable, is, that among the few articles of household decoration of which the humble mansion of Thomas Watt and his sons could boast, were portraits of John Napier, the celebrated inventor of logarithms, and of Sir Isaac Newton.

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* Memorials of Watt, pp. 137 and 138.

These paintings are not of any very extraordinary pretensions on the score of art; the Newton, in particular, appearing to be a rather indifferent copy of not the best original. But the portrait of Napier is, irrespective of the history of Watt, of high interest, having every appearance of being either an original likeness, or at the least a contemporary copy of a good original, painted with care and fidelity. It is "without the cowl;" and appears to be the *vera effigies* of the sage, in those latest years of his life when snows of age had fallen on his head, and furrows of ancient thought had been ploughed deep upon his brow; when not only had his great work, the 'Mirifici Canonis Logarithmorum Descriptio,' been for some years made public, but even his 'Rhabdologia,' the last of all his works which appeared in his lifetime, was either published, or, at least, completed in its author's mind; for his left hand is represented as resting on a set of those figured implements of calculation, commonly known in his own country as "Neper's Bones."

In precincts hallowed by such Lares and Penates, and not devoid of the "imagines majorum,"—for portraits of Thomas Watt and Margaret Sherrer, as well as of James Watt, sen., of Greenock, and of Agnes Muirheid, then hung on their walls, and are now associated in a family series with those of their more illustrious descendant—the boy grew to the age of nearly eighteen, a contemplative, yet far from inactive youth. But his ideas were destined to be expanded, and his hopes to be checked, amid increasing reverses of his father's fortunes. So far, indeed, did those reverses at last extend, that it became necessary that both of Mr. Watt's sons, at as early an age as possible, should be trained to rely for their future comfort or distinction, and indeed for their very subsistence, on their own independent and unaided exertions.

From the aptitude which James displayed for all kinds of ingenious handiwork, and in accordance with his own deliberate and earnest choice, it was decided that he should proceed to qualify himself for following the trade of a mathematical-instrument-maker;—a career in which, besides the prospect of turning to good account his habits of industry, his accuracy of eye, and neatness of hand, he doubtless foresaw opportunities, such as no other calling within his reach was likely to afford, of gratifying his thirst for the knowledge of physical science.

With these views he came to Glasgow in June, 1754, being then eighteen years of age, and remained under the roof and care of his maternal relations, the Muirheids, till the month of May in the following year. There is still extant a document which bears amusing testimony to the almost primitive simplicity with which his migration from the paternal home was performed. It is entitled, in the clerkly hand of their youthful possessor, "A list of James Watt's clothes taken to Glasgow;" and, after certain "silk stockings," "ruffled shirts," and "cut velvet" waistcoats, there follow in it "one working ditto," "one leather apron," "a pair bibels," about a score of the most needful tools of carpentry, and a quadrant. Of all the latter items (with the exception of the "pair bibels," which were, it seems, somehow or other unaccountably left behind!) it will soon be seen he made dexterous and successful use.

During his stay at that time in Glasgow, young Watt enjoyed the advantage of being introduced to the notice and acquaintance of several of the most learned Professors in the University, through the instrumentality of his mother's kinsman Mr. George Muirhead, who had just then exchanged the Professorship of Oriental languages for that of Latin, and was associated with his colleague Professor Moor in scholarlike labours which have honourably perpetuated his name.

Watt, however, was not so fortunate as to become the pupil of any Professor in the ancient University, which the talents of men such as Adam Smith and Robert Simson then so greatly adorned; and the youthful student has himself recorded that he never attended any course of lectures delivered within the walls, or by the teachers of the College. But he at once gained the favourable notice of Dr. Dick, who was joint Professor of Natural Philosophy with his father from 1751 to 1757, to whose society the subjects of his pursuits formed an immediate attraction, and of whose abilities, as well as of the kind interest he manifested in his success, Mr. Watt always spoke in terms of the most grateful praise. Dr. Dick, having observed the qualifications of his young friend, and being consulted as to his outset in life, strongly recommended his proceeding to London, to acquire better instruction in the art which he designed to practice, than could at that time be gained in Glasgow, or, indeed, anywhere in Scotland; at the same time furnishing him with a personal introduction which proved very serviceable in obtaining for him the advantage of such tuition.

It being arranged that young Watt should follow this counsel, on the 7th of June, 1755, he set off for the great metropolis, in charge of his connection Mr. John Marr,* who, we believe, afterwards became the captain of an East Indiaman, but soon after their arrival in London accepted the office of naval instructor on board the Hampton Court, a seventy-gun ship, then lying at anchor in the Thames. They travelled, as was common a century ago, on horseback, riding the same horses throughout the journey, which they performed in twelve days, including two of partial or entire rest. "There was in the days of which I write," says Sir Walter Scott, "an old-fashioned custom on the English road, which I suspect is now obsolete, or practised only by the vulgar. Journeys of length being made on horseback, and, of course, by brief stages, it was usual always to make a halt on the Sunday in some town where the traveller might attend Divine service, and his horse have the benefit of the day of rest, the institution of which is as humane to our brute laborers as profitable to ourselves."† Their route was by Coldstream, Newcastle, Durham, York, Doncaster, Newark, and Biggleswade; and the principal note made by the young traveller in the new scenes through which he now passed, is a laconic one:—"I like the country very [well], *but think the people are very sharp.*" It must be added in explanation of this concise and "canny" conclusion, tha nearly one-third of the time occupied on the road was spent i riding through *Yorkshire;* in fact, the letter which contains it was written at *York.*

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* Mr. Marr's wife was a cousin-german of Mr. Watt.

† Sir Walter Scott, Rob Roy, chap. iv., Abbotsford edition, vol. iii., p. 59.

On their arrival in London no time was lost in endeavourin to find a fitting instructor in the mathematical-instrument line,—a task which at first appeared likely to prove one of unexpecte difficulty; for the number of masters skilled in that scientifi trade was then small, and it was "the custom of London" not t dispense with the regular apprenticeship of seven years on indenture. "I have not yet got a master; we have tried several; the all make some objection or other," writes the poor lad. "I fin that if any of them agree with me at all, it will not be for les than a year; and even at that time [they] will be expecting som money."[†] Having been nurtured in the observance of rigid frugality, and being most dutifully anxious to avoid all encroachment on his father's means, which seem to have diminished in a inverse ratio to his own necessities, his narrow finances were no a cause of uncomfortable apprehension; and altogether his earl impressions of life in London were very far from being either joyous or encouraging.

But by degrees a little light began to dawn above the di horizon. "Yesterday," writes Mr. Marr to Mr. Watt, sen., a Greenock,[‡] "your son began to divert himself in cutting letter and figures, &c., in the shop of Mr. Neale, watchmaker, fro whom I had the small patent globes. Mr. Neale is the frankes tradesman of any of the fraternity I have seen. . . . In th meantime I shall endeavour to see him employed at Mr. Neale's who inclines to have some of his work to show." His specimen having been approved of, we find him, by the first week of July through the exertions of Mr. Short, (a valuable friend whom Dr

[*] Mr. Watt to his father, York, 12 June, 1755.

[†] Mr. Watt to his father, London, 1 July, 1755.

[‡] Mr. Marr to Mr. Watt, senior, London, 24 June, 1755.

Dick's recommendation had procured him,) at work on the brass part of Hadley's quadrants, with Mr. John Morgan, mathematical-instrument-maker in Finch Lane, Cornhill,—"a man," soon afterwards writes his youthful disciple, "of as good a character, both for accuracy in his business and good morals, as any in his way in London. Though he works chiefly in the brass way, yet he can teach me most branches of the business, such as rules, scales, quadrants, &c."* "Within the bills of mortality," adds Marr, "he could not have found a man better recommended for good nature and ingenuity than Morgan."† And, "If it had not been for Mr. Short," writes the lad, "I could not have got a man n London that would have undertaken to teach me, as I now ind there are not above five or six that could have taught me all I wanted."‡

An agreement was soon concluded, with the approbation of Mr. Watt, sen., for his son receiving a year's instruction from Mr. Morgan, for which he was in return to pay twenty guineas, and give his labour for that period in the business. After this his progress was rapid and steady. By the 5th of August, he had made a brass parallel ruler 18 inches long, and a brass scale of the same length, and was about to finish some of Hadley's quadrants; by the 23rd of that month, he had done a Hadley's quadrant better than his master's apprentice, "who had been two years with him." "Very few here," he says, "know any more than how to make a rule, others a pair of dividers, and such like, which they serve a seven years' apprenticeship to." In October he had begun to make rules, which it was then a most difficult matter to get good, "there being only one man who could make them perfectly well, and he having lately taken to other work." In November he was busy with azimuth compasses; by December, 1755, he "could work tolerably well;" and expected that by April he would understand so much of his business as to be able to work for himself, or to be an assistant to his father. When April arrived he was to make a brass sector, a theodolite, and some other instruments of the better sort; "and then," he writes, "I think I shall be able to get my bread anywhere, as I am now able to work as well as most journeymen, though I am not so quick as many."* And when his year's toil was completed, and the "leafy month of June" had again come round, he announced, with some reasonable pride, that he could now make "a brass sector with a French joint, which is reckoned as nice a piece of framing work as is in the trade."†

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* Mr. Watt to his father, London, July 21st, 1755.

† Mr. Marr to Mr. Watt, senior, London, Aug. 6th, 1755.

‡ Mr. Watt to his father, London, Sept. 2nd, 1755.

But all this early expertness was not acquired for nothing; it cost him a constant and hard struggle to reach that step on the upward ladder; and his labours were rendered the more severe by the state of his health, from which he had of late greatly suffered. He had not only, as was his wont, led a life of the most regular and unremitting industry, and spared no exertion by which he might diminish to his father the cost of this part of his education; but his endeavours to attain that end were accompanied by a rigid self-denial, on which, however in itself exemplary and laudable, it is almost painful to reflect. Lodging, it is believed, under the roof of his master, but not receiving from him any of his board, the cost of his food was in all but eight shillings a-week; lower than that, he writes, he could not reduce it "*without pinching his belly.*" Even of that pittance a great portion was earned by himself; for he found that he was able to "win" some money on his own account by rising still earlier than he had to go to his master's work. The bread so bought must have tasted sweet indeed to his lips; but at night he was thankful enough to get to bed "with his body wearied, and his hand shaking, from ten hours' hard work;" "we work," he says, "to nine o'clock every night, except Saturdays." In his letters to his home, while describing the frugality of his way of life, and regretting the charge his living must be to his father, on whom he fervently prays that the blessing of God may rest, he repeatedly adds that he is striving all he can to improve himself, that he may be the sooner able to assist him, and to ensure his own maintenance.

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* Mr. Watt to his father, London, April 20th, 1756.

† Mr. Watt to his father, London, June 19th, 1756.

With such motives to exertion, and such sentiments and habits, it will readily be conceived that he considered his year in London as admitting of no holiday indulgence. So earnestly was he bent on self-improvement in the way of his business, and so entirely were his whole time and strength engaged in the constant exertion which that required, that only on two occasions,—the arrival of the King from abroad, and a proclamation of war against France,—does the uniformity of his industry appear to have been diversified, even by the sight of such pageants as every metropolis from time to time affords to the eyes of the poorest of its inhabitants. Indeed, so far was he from allowing any occupation of his time in even receiving or giving the news of the day, that the only allusion which his letters of that period contain relative to such subjects is the emphatic and summary conclusion, that "*as for news, there is no believing anything that is said;*"—a maxim which, in other days than his, may still perhaps be deemed not altogether devoid of salutary truth.

An unexpected danger at that time hung over his destiny, which might have cut short, at least for a season, his projects of further improvement in natural science, and postponed *sine die* his return to Glasgow College, with all its interesting consequences. This sword of Damocles was the chance of being impressed as a seaman for the navy. He writes, in the spring of 1756, that he avoids "a very hot press just now by seldom going out." And on a later day he adds, "they now press anybody they can get, landsmen as well as seamen, except it be in the liberties of the City, where they are obliged to carry them before my Lord Mayor first; and unless one be either a 'prentice or a creditable tradesman, there is scarce any getting off again. And if I was carried before my Lord Mayor, I durst not avow that I wrought in the City, it being against their laws for any unfreeman to work, even as a journeyman, within the Liberties."*

At the close of his engagement with Mr. Morgan, when he "had no doubt he could have got encouragement from either his master or some other,"—after long contending with the badness of his health,—he found himself compelled by "violent rheumatism," "a gnawing pain in his back," and "weariness all over his body," to seek the benefit which he expected to derive from his native air, and the ride homewards. So, in the end of August, 1756, he took leave of London and of Mr. Morgan, (who, dying in 1758, was not destined to witness the future success of his pupil,) and to revive his drooping health and spirits, he returned to his own country and friends;—first, however, making a small investment of about twenty guineas in half a hundred additional tools, with "absolute necessary" materials for "a great many more that he knew he must make himself" together with a copy of 'Bion's Construction and Use of Mathematical Instruments,'—a copious and useful treatise on the different branches of his intended trade. This was the first edition of the translation of M. Bion's work, by Edward Stone, an excellent, though self-taught, mathematician, a native of Scotland; it was a great enlargement of the original, and two editions of it were subsequently published in folio, bearing the dates of 1758 and 1759, together with a supplement.

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* Mr. Watt to his father, London, March 31st, 1756.

CHAPTER V.

MR. WATT'S EMPLOYMENT BY THE COLLEGE OF GLASGOW—HIS ESTABLISHMENT WITHIN ITS WALLS AS MATHEMATICAL-INSTRUMENT-MAKER TO THE UNIVERSITY—PROGRESS IN HIS BUSINESS—SHOP-KEEPING—HIS CONSTRUCTION OF ORGANS AND OTHER MUSICAL INSTRUMENTS—INSTRUMENTS OF HIS MANUFACTURE STILL IN EXISTENCE—CHANGE OF ABODE—HIS MARRIAGE—MACHINE FOR DRAWING IN PERSPECTIVE.

AN occasion soon presented itself for the advantageous employment of that little stock in trade which we have just described, as well as the newly-acquired skill of its owner. On the 25th of October, 1756, he writes from Glasgow to his father:—"I would have come down [to Greenock] to-day, but that there are some instruments that are come from Jamaica that Dr. Dick desired that I would help to unpack, which are expected to-day." The instruments here spoken of formed a valuable collection, which had been completed at great cost by the best makers in London, for their late proprietor Mr. Alexander MacFarlane, a merchant, long resident in Jamaica, and a cadet of the ancient feudal house of Macfarlane of that Ilk; who seems, amid his mercantile pursuits, not to have forgotten the motto of his family—*Astra castra, Numen lumen;*"—"*The stars my camp, the Lord my light;*"—and who, dying in 1755, bequeathed the contents of his observatory to the university in which he had received his education. The great astronomer Oltmanns, the companion of Humboldt, in mentioning, among some observations from which various latitudes and longitudes in the West Indies were accurately determined, those which Mr. Macfarlane had made, at Port Royal, near Kingston, Jamaica, (Phil. Trans. for 1723. p. 235, and for 1750,

p. 523), has said: "Macfarlane was provided with excellent English instruments, and very skilful in the theory and practice of astronomy."* The minute of a University meeting on the 26th of October, bears that "Several of the instruments from Jamaica having suffered by the sea-air, especially those made of iron, Mr. Watt, who is well skilled in what relates to the cleaning and preserving of them, being accidentally in town, Mr. Moor and Dr. Dick are appointed to desire him to stay some time in town to clean them, and put them in the best order for preserving them from being spoiled." On the 2nd of December the same records bear that "a precept was signed to pay James Watt five pounds sterling for cleaning and refitting the instruments lately come from Jamaica;"—this being, in all probability, the first money he had earned on his own account since the termination of his brief apprenticeship.

His next object was to endeavour to establish himself in the way of his trade in the city of Glasgow; but here he was met by obstacles of the same sort as those which in London had first well-nigh excluded him from the brief instruction which he sought, and then might have consigned him, without hope of rescue, to the embrace of the pressgang. Neither being the son of a burgess, nor having, as yet, married the daughter of one, nor having served a regular apprenticeship to a *craft*, he was visited, by tradesmen of more arrogant and far more unfounded pretensions than the modest youth whom they persecuted, with a sort of temporal excommunication; and was forbidden to set up even a humble workshop, himself its solitary tenant, within the limits of the burgh. He now signally found the advantage of that academical support which the University uniformly extended to him. By midsummer, 1757, he had received permission to occupy an apartment and open a shop within the precincts of the College, and to use the designation of "Mathematical-instrument-maker to the University;" and, though it does not appear that any contemporaneous record has been preserved in the archives of the University of the date of the workshop having been assigned to him, on the 27th of November, 1759, directions were given for having "the room above Mr. Watt's workshop" repaired.* In the autumn of 1757, the foundation-stone of an astronomical observatory, to receive the collection of instruments which he had repaired and set up, and to be called the Macfarlane Observatory, was laid, he being then twenty-one years of age. At the same time, however, he had the sorrow and misfortune to lose his able and true friend, Dr. Dick; and the result, in a pecuniary point of view, of this first year of his business, was very far from being a hopeful one.

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* "Recueil d'Observations Astronomiques, Voyage de Humboldt et Bonpland," Quatrième Partie, tome ii., p. 589, ed. 1810.

On the 15th September, 1758, (the year in which his old master, Morgan, died,) he thus writes from Glasgow to his father:—"As I have now had a year's trial here, I am able to form a judgment of what may be made of this business, and find that unless it be the Hadley's instruments, there is little to be got by it, as at most other jobs I am obliged to do the most of them myself; and as it is impossible for one person to be expert at everything, they very often cost me more time than they should do. However, if there could be a ready sale procured for Hadley's quadrants, I could do very well, as I and one lad can finish three in a week easily; and selling them at 28*s.* 6*d.*, which is vastly below what they were ever sold at before, I have 40*s.* clear on the three. So it will be absolutely necessary that I take a trip to Liverpool to look for customers, and hope that upon the profits of what I shall be able to sell there, I can go to London in the spring, when I make no doubt of selling more than I can get made; all which I want your advice on. And if that does not succeed, I must fall into some other way of business, as this will not do in its present situation." The sale, however, of the profitable Hadley's instruments appears to have increased at home so much, as to have rendered the proposed speculative trading voyage to Liverpool unnecessary.

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* See 'Deeds instituting Bursaries, Scholarships, and other Foundations in the College and University of Glasgow,' 1850: 4to., p. 215.

From the advertisement already referred to, dated October 22, 1759, of the engraved map of the river Clyde, as "to be sold by James Watt, at his shop in the College of Glasgow," as well as from the entry in the College records of the repairs to be done in "the room above Mr. Watt's workshop," we know that, up to that time at least, he continued to use the shelter of the academic walls for the purposes of his trade. By the 7th of October in that year, he appears to have entered into a sort of partnership with a Mr. John Craig, to carry on and extend the business in which he was engaged, continuing to occupy his rooms and workshop in the College till 1763.

A Journal of the partnership concern, kept from October, 1759, till April, 1765, commences with the following entry: "An Inventory of Tools, Goods, &c., belonging to us, James Watt and John Craig, each one-half. Taken Oct. 7th, 1759, at Glasgow;" and then enumerates a variety of mechanical tools, from a turning-lathe to a flatting-mill; with philosophical instruments, chiefly mathematical and optical, from the familiar "Hadley's quadrants" to microscopes and sea-compasses; the whole to

the value of	£91	19	3½
Which, with "cash on hand," . . .	108	0	8½
Made the little stock in trade amount to .	£200	0	0

A small but steadily increasing traffic brought the "ready-money sales," towards the end of the period over which the Journal extends, up to about 50*l.* per month, or 600*l.* per annum; a large portion of which, however, must have gone to pay for materials and the wages of workmen. James Watt is throughout credited with a salary of 35*l.* per annum; Craig appearing to have taken no share in the manufacturing part of the business, but only (as is shown by a memorandum in the Journal) to have been book-keeper to the concern, and to have advanced the greater portion of the requisite funds. One journeyman throughout the year, and three or four others, from time to time, as occasion required, were all that Mr. Watt at first found it necessary to employ; but before the end of 1764 their number had increased to sixteen "of all arms." Among their names we find those of three Gardners,—Alexander, David, and John,—of whom one at least was long afterwards known in Glasgow as a well-instructed and reputable philosophical-instrument-maker. From the accounts of the business coming to a close in 1765, and Mr. Watt having said in a letter to Mr. Boulton in 1768, "about three years ago, a gentleman who was concerned with me died," we conclude that the termination of the partnership is thus explained.

In the retired course of life which, from choice as well as necessity, he appears to have followed, manual labour and mental study were blended in pretty equal proportions, but idleness or mere amusement had certainly no share. He ardently seized every opportunity of extending his acquaintance with the various branches of physical philosophy, and of investigating the principles of its phenomena, as if prophetically conscious that to his untaught but earnest apprehension might be revealed those secrets which hitherto had been hidden even from the wise and learned; endeavouring,—to use an expression of his own,—"to find out the weak side of Nature, and to vanquish her,"—"for Nature," he again says, "has a weak side, if we can only find it out!" Beyond the necessity for some daily labour in order to earn his daily bread, and his hope,—often, as will be seen, very uncertain,—of future independence, he had little else than the pleasure he found in philosophical pursuits to stimulate or reward his zeal; the toils of his business were severe, and the profitable returns but small, while of those whose society was open to him, there were few indeed who possessed either an equality of learning or a community of tastes with himself. But in his endeavours to subjugate, by the resources of practical art, those natural difficulties which presented themselves to his hand or eye, nothing seemed to deter his zeal or baffle his penetration; a very curious proof of which was afforded by his frequent construction, about the period at which we have now arrived, of musical instruments of perfect compass and tone, although he had himself, by nature, an absolute deficiency of all musical ear.

Professor Robison, in a document from which we shall hereafter have to make large quotations, gives a remarkable instance of this:—"A mason-lodge in Glasgow wanted an organ. The office-bearers were acquaintances of Mr. Watt. We imagined that Mr. Watt could do anything; and, though we all knew that he did not know one musical note from another, he was asked if he could build this organ. He had repaired one, and it had amused him. He said, 'Yes;' but he began by building a very small one for his intimate friend Dr. Black, which is now in my possession. In doing this, a thousand things occurred to him which no organ-builder ever dreamed of,—nice indicators of the strength of the blast, regulators of it, &c., &c. He began to the great one. He then began to study the philosophical theory of music. Fortunately for me, no book was at hand but the most refined of all, and the only one that can be said to contain any theory at all,—Smith's Harmonics. Before Mr. Watt had half finished this organ, he and I were completely masters of that most refined and beautiful theory of the beats of perfect consonances. He found that by these beats it would be possible for him, totally ignorant of music, to tune this organ according to any system of temperament; and he did so, to the delight and astonishment of our best performers. In prosecution of this, he invented a real monochord of continued tone; and, in playing with this, he made an observation which, had it then been known, would have terminated a dispute between the first mathematicians in Europe,—Euler and D'Alembert; which completely establishes the theory of Daniel Bernouilli, who differed from both of those gentlemen, about the mechanism of the vibration of musical chords; and as completely explains the harmonic notes which accompany all full musical notes, overturning the theories of Rameau and Tartini."

The date of the construction of those organs is pretty exactly fixed by two letters from his friend Alexander Cumming, F.R.S., a very ingenious adept in similar pursuits, then resident in London, whose name is well known by his meritorious publications on subjects of mechanical interest; such as, the elements of clock and watch work, the influence of gravitation as a mechanical power, and the effects of cylindrical instead of conical carriage-wheels. Writing to Mr. Watt on the 27th December, 1761, Mr. Cumming approves of his scheme for an organ, supplies him with a note of the prices of organ-pipes, and inquires "How gets on fiddle making?" And on the 8th September, 1762, he expresses himself as "glad of his success in organ building," and describes the magnificent instrument of the same kind which he had himself constructed for Lord Bute, at a cost of £2000. Mr. Cumming adds this further notice of his own proceedings in the way of ingenious musical mechanism:—"I have proposed an improvement on the musical glasses, (that are played by moving the wet fingers along the brim,) by making them play with keys; but, as I have as great a demand in the way of my business as I can well answer, have put off the thoughts of that and some other experiments till I have more leisure." The organs here spoken of were not the only produce of Mr. Watt's musical manufacture; and guitars, flutes, and violins are still in existence, preserved with care by their respective possessors, as curious instances of so extraordinary a parentage; which, indeed, when we consider the co-existence of a physical deficiency in a point apparently essential, must be viewed as little short of a miracle in the works of untutored handicraft.

Succeeding beyond expectation in his first attempts in that novel line, it is wonderful how many dumb flutes and gouty harps, dislocated violins and fractured guitars, nervous violdigambas, hysterical mandolins, and thorough-basses suffering from hoarseness, came thenceforward to be cured by him of their complaints, and restored to health and harmony.

It might have been supposed that they could scarcely have gone to a worse doctor, as mere neatness of hand, devoid of all ear for musical notes, could not reasonably have been expected to suffice for the successful treatment of such patients. Yet, from the rapid increase in the extent of that peculiar department of his business, it seems certain that the cures he wrought were very complete and satisfactory.

Of one of the organs constructed by Mr. Watt, the late Mr. Archibald Maclellan, who, for thirty years prior to his decease in 1854, was a prominent member of the Town Council of Glasgow, and a zealous patron of the fine arts, became the possessor. In his last illness, Mr. Maclellan dictated the following *historiette*, which is not without interest; although the assertion with which it sets out, of Mr. Watt's fondness for music, needs, as we have seen, very great qualification, and might better have been limited to the predilection, which he no doubt did possess, for constructing musical instruments:

"MUGDOCK CASTLE, 14 Sept., 1854.

"It is well known that the great James Watt was fond of music, and while in Glasgow constructed more than one organ. One of these was a small instrument, about three feet square, in the form of a small table, but having externally no appearance of a musical instrument. At this table, where his friends and he were sitting, the movement being concealed, Mr. Watt astonished them by the production of the music. This little table, about forty years ago, fell into the hands of the late Steven, the music-seller, in Wilson Street, who had an organ front with gilt pipes and sides placed on the top of the table, and gave it the shape it now bears. I bought it from Steven, and put an additional reed stop into it. It remains so at present. Such is the history of this interesting little instrument, and I think I need scarcely recommend it to my trustees as a fancy and a work of the great James Watt deserving of their notice and preservation. The instrument, when in proper tune, is of considerable power and very pleasing harmony, and, in my keeping, has been orthodox in its application, from 'Martyrs' to 'Old Hundred.'

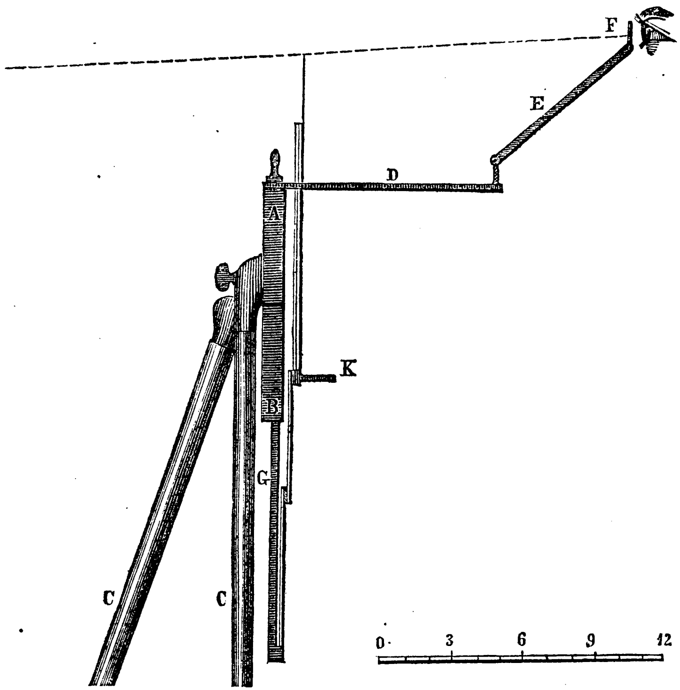
"ARCH'D M'LELLAN."

In 1763, Watt quitted his college rooms for a small abode in the city; a change made, probably, in contemplation of his marriage to his cousin, Miss Miller, which took place in July of the following year. The site of his new dwelling, or at least of the workshop in which his earliest experiments on the steam-engine were made, and which in all probability was under the same roof, is stated by Mr. Robert Hart to have been in or close to King Street. "In answer to my question about the site of this shop, Mr. Watt said, 'It was in a little court [at the] north end of the beef market; the house projects into the court; I think a carrier occupies it at present.' I think this was in the year 1813 or 1814. My brother and I went next morning and saw the house; a large door had been made in the end of it, to make it into a cart-house, and a carrier was loading his cart in it at the time. I think it stood where Millar's Place is, just in front of what was the inn door, as it was but a few yards from the north-east corner of the market, in a north-east direction." In 1770 it appears that he went through the "disagreeable operation" of removing his "household furniture and utensils to another house;" but, during the whole of his residence in Glasgow, he practised housekeeping, from necessity as well as choice, on a very humble scale. After his marriage, however, his dwelling was enlightened by a charming presence, which "made a sunshine in that shady place." "I have not entered," says Miss Campbell, "into any of the interesting details my mother gave me of Mr. Watt's early and constant attachment to his cousin Miss Miller; but she ever considered it as having added to his enjoyment of life, and as having had the most beneficial influence on his character. Even his powerful mind sank occasionally into misanthropic gloom, from the pressure of long-continued nervous headaches, and repeated disappointments in his hopes of success in life. Mrs. Watt, from her sweetness of temper, and lively, cheerful disposition, had power to win him from every wayward fancy,—to rouse and animate him to active exertion. She drew out all his gentle virtues, his native benevolence, and warm affections."

In 1765, Mr. Watt contrived an ingenious machine for drawing in perspective, of which he has left the following description, together with drawings which are here engraved on wood (see page 39); and the instrument may be considered a sort of connecting link between his mathematical-instrument-making and his surveying. His first perspective machine, like his first organ, was constructed for his friend Dr. Black.

Perspective Machine.

"The perspective machine was invented about 1765, on the following occasion. My friend, Dr. James Lind, brought from India a machine, invented by some English gentleman there,—I believe, a Mr. Hurst,—which consisted of a board, fixed on three legs perpendicularly, upon which, close to the bottom and near the ends, were fixed two small friction-wheels, upon which a horizontal ruler rested, and could be moved endways horizontally, and this ruler was about twice the length of the board. On the middle of this ruler was fixed a perpendicular ruler, reaching a little above the upper edge of the board, and in this ruler there was a groove similar to that of the slip of a sliding rule, which was also, like that, furnished with a slider which could freely move up and down in it, and the upper end of which, being pointed, served for an index. In the bottom of the groove in the perpendicular ruler there was a slit cut quite through the ruler, nearly from one end to the other. In the lower end of the slider was fixed a pencil, the point of which reached quite through the ruler to the paper to be drawn upon, which was stretched upon the board. An arm projecting forward was fixed to one of the upper corners of the board, (I do not remember how,) and upon its end nearest the draughtsman it carried a sight or eye-piece, consisting of a small piece of metal with a small hole in it, and this eye-piece was elevated about half the width of the board above its upper edge. The rulers, sliders, &c., were, I think, made of brass, consequently heavy, but moved easily on the pulleys, or friction-wheels.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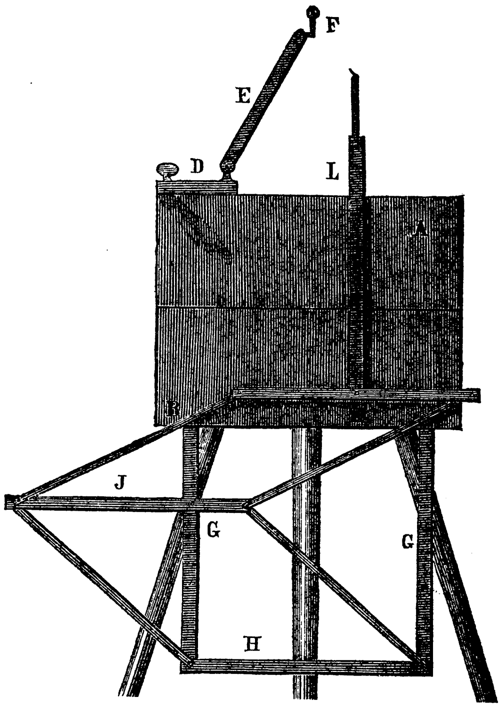
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"In using the machine, the board being placed at right angles to a line supposed to be drawn from the middle of the object which was to be delineated, and the sight adjusted so as to give a proper scale, the socket of the pencil was taken in the hand, the eye applied to the sight, and the index or acute top of the slider was made to travel over the lines of the object to be delineated, which it was enabled to do by a composition of the horizontal motion of the lower ruler on the wheels, and of the perpendicular motion of the slider in the upright ruler; the pencil then described the lines upon the paper. This instrument very readily described perpendicular or horizontal lines, as these accorded best with its natural motions. But in diagonal or curved lines it was difficult to make the index follow them exactly, and the whole motions were heavy and embarrassing to the hand. Moreover, the instrument was heavy and too bulky.

"I wished to make a machine more portable, and easier in its use; and at the suggestion of my friend, Mr. John Robison, I turned my thoughts to the double parallel ruler, an instrument then very little known, and not at all used that I know of. After some meditation, I contrived the means of applying it to this purpose, and of making the machine extremely light and portable.

"The machine consisted of a box about an inch and a half deep on the outside, thirteen inches long, and five inches wide, and hinged so that when opened it formed a flat board (AB) of thirteen inches long and ten inches wide, on which the paper was stretched. It was kept open by means of three legs, (CCC,) which were fastened to the back part of it, and served to support it at a proper height. From the right hand upper corner of this box or board, a jointed arm (DE) projected forward, to carry the eye-piece or sight, (F,) which could, by means of the joints, be adjusted higher or lower, nearer to, or further from the board, as might be required. To the lower edge of the board were attached two thin slips of wood, (GG,) ten inches long and ten inches apart, and to the lower ends of these slips was attached the lower ide of a double parallel ruler, (HJK,) every member of which as ten inches long between the centres, so that, when fully open, t formed two squares joined by one side of each, and in other tates formed lozenges, or rhombuses of different degrees of bliquity. This double parallelogram was formed partly of thin lips of wood, and partly of brass much hammer-hardened, and ll very light. To the middle (K) of the upper side of the higher arallelogram, was fixed, at right angles, upwards, another slip f wood, (L,) about eleven inches long, and ending in a brass oint which served for an index, which, by the construction, ould be moved equally easily in every direction, and with very ittle friction; and, at the same time, all the positions of the ulers were always parallel to each other. A pencil, pressed pon by a spring, was fixed in the junction of the perpendicular lip or index at K.

"A paper being stretched upon the board, and the sight beng moved to a proper distance from the board, (generally about ighteen inches,) the hand being applied to the pencil socket, (for the pencil was not pressed upon by the hand,) the upper oint of the index was led along the lines of the objects inended to be delineated; and, when perpendicular lines occurred, he index pointing to the upper end of them, the finger of the eft hand being applied to the board touching the perpendicular lip, and the pencil drawn downwards, the line would be straight. In the same way, the horizontal slip served as a guide for horizontal lines; all others were drawn by the eye guiding the index, and, if the paper was smooth, could be drawn very correctly.

"The whole of the double parallelogram and its attached slips, (which latter were contrived to be easily separated from the board,) were made capable of being readily folded up, so as to occupy only a small space in the box formed by the board, when folded up. The sight-piece also folded up, and readily found its place in the box, which also contained screws for fixing on the legs of the instrument; and the box, when shut, could be put into a great-coat pocket. The three legs were made of tinned iron, tapering, and one a little smaller than another, so that they went into one another, and formed a walking-stick about four and a half feet long.

"I made many of these instruments about the time mentioned,—perhaps from fifty to eighty. They went to various parts of the world; among other places several went to London, where George Adams, senr., copied and made them for sale, putting his own name on them; and, *as I have been told*, in a book which he published, describing various instruments, he took the credit of the invention to himself, or expressed himself so as to leave that supposable; but I have not seen the book as far as I can remember, but have seen the instruments with his name on them."

CHAPTER VI.

MR. WATT'S INTRODUCTION TO DR. BLACK, AND TO PROFESSOR ROBISON—DR. BLACK'S HISTORY OF THEIR FRIENDSHIP, AND OF MR. WATT'S IMPROVEMENTS ON THE STEAM-ENGINE—DR. ROBISON'S HISTORY OF HIS ACQUAINTANCE WITH MR. WATT—ACCOUNT OF HIS CHARACTER, ABILITIES, DISPOSITIONS, HABITS, AND PURSUITS—EXPERIMENTS ON MODEL OF NEWCOMEN'S ENGINE—INVENTION OF SEPARATE CONDENSER, AND FURTHER IMPROVEMENTS ON THE STEAM ENGINE.

IT was at this time that the young artificer's earnest devotion to philosophical pursuits, as well as his amiable and virtuous disposition, gained him the approving notice and enduring friendship of Dr. Black, who, in 1756, was appointed Professor of Anatomy, and, in 1757, Professor of the Practice of Medicine, in Glasgow College. It was also in the commencement of the winter of 1758–9 that he made the acquaintance of another able and ardent student, imbued with predilections similar to his own, Mr. John Robison, afterwards, by Dr. Black's recommendation, appointed to succeed Dr. B. as Lecturer on Chemistry in the University of Glasgow; and who subsequently became eminent as Professor of Natural Philosophy in that of Edinburgh. Both of these learned persons, owing to the accidental circumstance of their testimony having been called for on occasion of infringements of Mr. Watt's patents, at a period nearly forty years subsequent to their first meeting at Glasgow, have left interesting narratives of the rise and progress of their intercourse with Mr. Watt, and of the origin of his first and greatest invention, which, as they do honour alike to their authors and their subject, we do not hesitate to place before our readers. That by Dr. Black, which is by much the shorter of the two, had never been noticed by any of the previous biographers of Watt, nor, indeed, did its existence appear to have been known to them; while from D Robison's longer, but highly curious and important narrativ only a very brief extract was published by M. Arago.

History of Mr. Watt's Improvement of the Steam-Engine.

By JOSEPH BLACK, M. D.*

"I became acquainted with Mr. James Watt in the year 175 or 1758, at which time I was Professor of Medicine and Lecture of Chemistry in the University of Glasgow. About that time M Watt came to settle in Glasgow as a maker of mathematical instruments; but being molested by some of the corporations, who considered him as an intruder on their privileges, the University protected him by giving him a shop within their precincts, and b conferring on him the title of Mathematical Instrument Maker t the University.

"I soon had occasion to employ him to make some thing which I needed for my experiments, and found him to be a young man possessing most uncommon talents for mechanical knowledge and practice, with an originality, readiness, and copiousness of invention, which often surprised and delighted me in our frequent conversations together. I also had many opportunities to know that he was as remarkable for the goodness of his heart, and the candour and simplicity of his mind, as for the acuteness of his genius and understanding. I therefore contracted with him an intimate friendship, which has continued and increased ever since that time. I mention these circumstances only to show how it happened that I was thoroughly acquainted with the progress of his inventions, and with the different objects that engaged his attention, while I remained at Glasgow, and, in a great measure, ever since.

"A few years after he was settled at Glasgow he was employed by the Professor of Natural Philosophy to examine and rectify a nall workable model of a steam-engine, which was out of order. his turned a part of his thoughts and fertile invention to the ature and improvement of steam-engines, to the perfection of eir machinery, and to the different means by which their great onsumption of fuel might be diminished. He soon acquired such reputation for his knowledge on this subject, that he was employed plan and erect several engines in different places, while at the ame time he was frequently making new experiments to lessen e waste of heat from the external surface of the boiler, and from hat of the cylinder.

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* The original document is in the hand-writing of Dr. Black. On the envelope in which it is enclosed Dr. B. has written, "Mr. Watt's law-suit, 1796–97."

"But after he had been thus employed a considerable time, he erceived that by far the greatest waste of heat proceeded from he waste of steam in filling the cylinder with steam. In filling he cylinder with steam, for every stroke of the common engine a reat part of the steam is chilled and condensed by the coldness f the cylinder, before this last is heated enough to qualify it for eing filled with elastic vapor or perfect steam; he perceived, herefore, that by preventing this waste of steam, an incomparably greater saving of heat and fuel would be attained than by any other contrivance. It was thus, in the beginning of the year 1765, that the fortunate thought occurred to him of condensing the steam by cold in a separate vessel or apparatus, between which and the cylinder a communication was to be opened for that purpose every time the steam was to be condensed; while the cylinder itself might be preserved perpetually hot, no cold water or air being ever admitted into its cavity.

"This capital improvement flashed on his mind at once, and filled him with rapture; and he immediately made a hasty trial of it, which satisfied him of its value, employing for this purpose a large brass syringe which he borrowed from a friend."

Such is the first part of the concise, but emphatic and comprehensive account given by Dr. Black; the remainder of which we reserve till somewhat later in our narrative. In the meantime, we proceed to give the greater portion of that of Dr. Robison, which, entering more into detail, seems more entirely to place us, as it were, in the very presence, and reveal to us the whole cour of thought and inquiry, of his inventive companion and frien According to Mr. Watt's own statement, to Robison belongs t honour of having been the first who drew his attention to the su ject of steam-engines;—in 1759 even suggesting their applic tion to "the moving of wheel-carriages," and to other purposes

Narrative of Mr. Watt's Invention of the Improved Engine.

By Professor Robison.

"My acquaintance with Mr. Watt began in 1758. I was the a student in the University of Glasgow, and studying the scienc which I now profess to teach, Natural Philosophy. The Unive sity was then building an astronomical observatory. Mr. Wat came to settle in Glasgow as a mathematical and philosophic instrument-maker, and was employed to repair and set up a ver noble collection of instruments bequeathed to the University b Mr. Macfarlane of Jamaica, a gentleman well known to the scien tific world. Mr. Watt had apartments and a workshop within th College. I had, from my earliest youth, a great relish for th natural sciences, and particularly for mathematical and mechanica philosophy. I was eager to be acquainted with the practice o astronomical observation, and my wishes were much encourage by the celebrated Dr. Simson, Professor of Geometry, Dr. Dick Professor of Natural Philosophy, and Dr. Moor, Professor of Greek;—gentlemen eminent for their mathematical abilities. Those gentlemen brought me with them into Mr. Watt's shop; and when he saw me thus patronised, or introduced, his natural complaisance made him readily indulge my curiosity."

Elsewhere,—in a letter to Mr. Watt, in 1799, on the death of Dr. Black,—Robison says, "My first acquaintance with Dr. Black began in your rooms, when you were rubbing up M'Farlane's instruments. Dr. Black used to come in, and, standing with his back to us, amuse himself with Bird's quadrant, whistling softly to himself, in a manner that thrilled me to the heart. . . In the end of 1758, when I went to sea, and had a favour to ask

: the professors, Dr. Black spoke very handsomely of me. This learned at my return; but we had no further acquaintance till ıen, or rather till 1764; and his marked attention to me (as he ıld me not long ago) was owing to my saying distinctly, and iving reasons for it, that Dr. Dick, my professor, had infinitely ıore knowledge than his successor, who was much more popular. ıdeed, Dr. Black has often said to me, that Dick was one of the ıost sensible and manly fellows he ever knew."

"After first feasting my eyes with the view of fine instruments, nd prying into everything, I conversed," continues Professor :obison, "with Mr. Watt. I saw a workman, and expected no ıore; but was surprised to find a philosopher, as young as myelf, and always ready to instruct me. I had the vanity to think ıyself a pretty good proficient in my favourite study, and was ather mortified at finding Mr. Watt so much my superior. But is own high relish for those things made him pleased with the hat of any person who had the same tastes with himself, or his ınate complaisance made him indulge my curiosity, and even ncourage my endeavours to form an intimate acquaintance vith him. I lounged much about him, and I doubt not, was requently teasing him. Thus our acquaintance began.

"It was interrupted in 1759. I left the College for the navy, vhere I was a midshipman four years, and was present in some f the most remarkable actions of that war. My health suffered o much by a seafaring life, that I was obliged to give it up, nuch against my inclination, and return to my academical habits. : was happy to find Mr. Watt settled in Glasgow, as fond of science as ever. Our acquaintance was renewed; I believe with nutual satisfaction, for I had now acquired some knowledge. I ıad lived in the closest intimacy with the late Admiral Sir Charles Knowles, and had been a good deal employed in marine surveys. I had been employed by the Admiralty to make the observations for the trial of Mr. Harrison's famous time-piece; in short, my habits had been such, that I reckoned myself more on a par with Mr. Watt, and hoped for a closer acquaintance. Nor was I disappointed. I found him as good and kind as ever, keen after the acquisition of knowledge, and well disposed listen to the information I could give him concerning thin which had not fallen in his own way. But I found him contin ally striking into untrodden paths, where I was always oblig to be a follower.

"Our acquaintance at this time became very intimate, and believe neither of us engaged far in any train of thought witho the other sharing in it. I had had the advantage of a mo regular education: this frequently enabled me to direct or co firm Mr. Watt's speculations, and put into a systematic form t suggestions of his inquisitive and inventive mind. This kind c friendly commerce knit us more together, and each of us kne the whole extent of the other's reading and knowledge. I w not singular in this attachment. All the young lads of our litt place that were in any way remarkable for scientific predilectio were acquaintances of Mr. Watt; and his parlour was a *rendezvo* for all of this description. Whenever any puzzle came in the wa of any of us, we went to Mr. Watt. He needed only to be prompted everything became to him the beginning of a new and serious stud and we knew that he would not quit it until he had either discov ered its insignificance, or had made something of it. No matte in what line,—languages, antiquity, natural history,—nay, poetr criticism, and works of taste; as to anything in the line of engi neering, whether civil or military, he was at home, and a read instructor. Hardly any projects, such as canals, deepening th river, surveys, or the like, were undertaken in the neighbourhoo without consulting Mr. Watt; and he was even importuned t take the charge of some considerable works of this kind, thoug they were such as he had not the smallest experience in. Whe to this superiority of knowledge, which every man confessed i his own line, is added the *naïve* simplicity and candour of Mr Watt's character, it is no wonder that the attachment of hi acquaintances was strong. I have seen something of the world and am obliged to say that I never saw such another instance o eneral and cordial attachment to a person whom all acknowledged be their superior. But this superiority was concealed under e most amiable candour, and liberal allowance of merit to very man. Mr. Watt was the first to ascribe to the ingenuity f a friend things which were very often nothing but his own surmises followed out and embodied by another. I am well entitled say this, and have often experienced it in my own case.

"But the circumstance which made Mr. Watt's acquaintance so valuable to me was the trait of character I have already mentioned. Everything became to him a subject of new and serious tudy,—everything became science in his hands; and I took the pportunity of offering my feeble aid, by prosecuting systemati-ally, and with the help of mathematical discussion, thoughts which he was contented with having suggested or directed. I hus shared the fruits of his invention; and with gratitude I here acknowledge my obligations to him for that strong relish which I hus acquired for rational mechanics, and which I have cultivated with great assiduity and pleasure all my life. I also shared with Mr. Watt a good deal of that subsidiary knowledge which he acquired as so many stepping-stones in his way to some favourite objects. He learned the German language in order to peruse Leupold's 'Theatrum Machinarum:'—so did I, to know what he was about. Similar reasons made us both learn Italian; and so of other things. And I cannot here pass over another circumstance which endeared Mr. Watt to us all: he was without the smallest wish to appropriate knowledge to himself; and one of his greatest delights was to set others on the same road to knowledge with himself. No man could be more distant from the jealous concealment of a tradesman; and I am convinced that nothing but the magnitude of the prospect which his improvement of the steam-engine held out to him and his family, could have made Mr. Watt refuse himself the pleasure of communicating immediately all his discoveries to his acquaintances. Nay, he could *not* conceal it; for, besides frankly imparting it to Dr. Black, to myself, and two or three more intimate friends, he disclosed so much of what he had been doing, that had it been London or Birmingham, I am confident that two or three paten would have been expedited for bits of his method, by bustli tradesmen, before he [would have] thought himself entitled solicit such a thing.

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"I doubt not but all this will be looked upon by some mere panegyric. The ignorant are insensible to the pleasures science, and have no notion of the attachments which this m produce; and the low-bred minds whose whole thoughts are fu of concealment, rivalship, and money-making, can hardly co ceive a mind that is not actuated by similar propensities. But have a better opinion of those* on whose feelings and judgme the issue of this cause is to depend. I wish to show these ge tlemen what were my opportunities of seeing the steps by whic Mr. Watt arrived at his final discovery; and I am not afrai that they will misinterpret the satisfaction I feel in having thi opportunity of expressing my sentiments of attachment to M Watt. There is perhaps but one other person now alive who† wa a witness to every step of the invention, and I regret exceedingl that his extreme illness makes it impossible for my friend to avai himself of his testimony. The thoughts of doing him an essen tial service have supported me in my journey hither, under ver considerable suffering; and when I find that not only the fortun but the fair name of a most worthy man is concerned, I thin that nothing less than life could have excused me from the soun duty of every good citizen—the support of eminent talents an worth against the vile aspersions of low-bred and ignorant pretenders.

"I think it was in the summer of 1764, or perhaps in th spring of that year,‡ that the Professor of Natural Philosoph the University desired Mr. Watt to repair a pretty model of ewcomen's steam-engine. This model was at first a fine playhing to Mr. Watt and to myself, now a constant visitor at the orkshop; but, like everything which came into his hands, it oon became an object of most serious study. This model being n exact copy of the real engine, a motion of the piston behoved o be the same, and the strokes to be much more frequent. In onsequence of this, the boiler was unable to supply more than a ew strokes. The boiler was made to boil more violently; but his, instead of continuing the motion by a more plentiful supply f steam, stopped the machine altogether; and we attributed this o the statical resistance to the entry of the injection, which ame from a height not much exceeding a foot. The injection-istern was placed higher, but without effect. It was long before he true cause was thought of, and in the meantime many obserations were made on the performance.

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* The special jury, in the cause "Boulton and Watt *versus* Hornblower an Maberly."

† Dr. Black.

‡ Mr. Watt has informed us that it was in the winter of 1763–4.

"Mr. Watt had learned from Dr. Black somewhat of his late iscovery of the latent heat of fluids and of steams. The Doctor ad established his doctrine by means of incontrovertible experiments in the case of congelation and liquefaction; but had not yet devised any very simple and popular experiments for showing the much greater quantity of heat which is contained in steam in a latent state. But the great variety of curious and abstruse phenomena which were explicable by this branch of the theory made it a subject of much conversation among the young gentlemen at college. Mr. Watt was one of the most zealous partisans of this theory,* and this little job of the model came opportunely in his way, and immediately took his whole attention. He made many curious experiments; and Dr. Black publicly acknowledges, in his lectures, his obligations to Mr. Watt for the chief experiments by which he illustrates and supports his theory. I had not yet studied chemistry, and Mr. Watt was my first instructor. My mind was fired with the inexhaustible fund of instruction and entertainment which I now saw before me: and I was more assiduous in my attendance on Mr. Watt's occupations than ever, and studied the little model as much as he did. He very early saw that an enormous quantity of steam was wasted. The great heat acquired in an instant by the cylinder, by the admission of a few grains of water in the form of steam, was an incontestable proof of the great quantity of fire contained in it; and as this could come only from the coals, Mr. Watt saw at once that the chief improvements that the engine was susceptible of must consist in contrivances for increasing the production, and for diminishing its waste. He greatly improved the boiler by increasing the surface to which the fire was applied; he made flues through the middle of the water; he placed the fire in the middle of the water; and made his boiler of wood, as a worse conductor of heat than the brickwork which surrounds common furnaces. He cased the cylinder, and all the conducting-pipes, in materials which conducted heat very slowly; he even made them of wood. After much acquaintance with his models, (for he had now made others,) he found that there was still a prodigious and unavoidable waste of steam and fuel, arising from the necessity of cooling the cylinder very low at every effective stroke; and he was able to show that more than three-fourths of the whole steam was thus condensed and wasted during the ascent of the piston. (Subsequent experiments, made with better apparatus, showed him that the waste was much greater than this.) I had seen all these contrivances, and many of the experiments, and had sometimes contributed my mite to lessen the expensive waste; but this great cause of loss seemed to be unavoidable.

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* *Note in the handwriting of Mr. Watt.*—"Dr. Robison is mistaken in this. I had not attended to Dr. Black's experiment or theory on latent heat, until I was led to it in the course of experiments upon the engines, when the fact proved a stumbling-block which the Doctor assisted me to get over.—J. W."

"At the breaking-up of the College, (I think in 1765,) I went to the country. About a fortnight after this, I came to town, and went to have a chat with Mr. Watt, and to communicate to him some observations I had made on Desaguliers' and elidor's account of the steam-engine. I came into Mr. Watt's arlour without ceremony, and found him sitting before the fire, aving lying on his knee a little tin cistern, which he was looking t. I entered into conversation on what we had been speaking f at last meeting,—something about steam. All the while, Mr. Vatt kept looking at the fire, and laid down the cistern at the ot of his chair. At last he looked at me, and said briskly, You need not *fash* yourself any more about that, man; I have ow made an engine that shall not waste a particle of steam. It hall all be boiling hot;—aye, and hot water injected if I please.' o saying, Mr. Watt looked with complacency at the little thing t his feet, and, seeing that I observed him, he shoved it away nder a table with his foot. I put a question to him about the ature of his contrivance. He answered me rather drily. I did ot press him to a further explanation at that time, knowing that had offended him a few days before by blabbing a pretty contrivance which he had hit on for turning the cocks of the engine. had mentioned this in the presence of an engine-builder, who was going to erect one for a friend of mine, and this having come to Mr. Watt's ears, he found fault with it.

"I was very anxious, however, to learn what Mr. Watt had contrived, but was obliged to go to the country in the evening. A gentleman who was going to the same house said that he would give me a place in his carriage, and desired me to wait for him on the walk by the river-side. I went thither, and found Mr. Alexander Brown, a very intimate acquaintance of Mr. Watt's, walking with another gentleman, (Mr. Craig, architect.) Mr. Brown immediately accosted me with, 'Well, have you seen Jamie Watt?'—'Yes.'—'He'll be in high spirits now with his engine, isn't he?' 'Yes,' said I, 'very fine spirits.' 'Gad,' said Mr. Brown, 'the condenser's the thing: keep it but cold enough, and you may have a perfect vacuum, whatever be the heat of the cylinder.' The instant he said this, the whole flashed on my mind at once. I did all I could to encourage the conversation, but was much embarrassed. I durst not appear ignorant of the apparatus, lest Mr. Brown should find that he had communicated more than he ought to have done. I could only learn that there was a vessel called a condenser, which communicated with the cylinder, and that this condenser was immersed in cold water, and had a pump to clear it of the water which was formed in it. I also learned that the great difficulty was to make the piston tight: and that leather and felt had been tried, and were found quite unable to stand the heat. I saw that the whole would be perfectly dry, and that Mr. Watt had used steam instead of air to press up his piston, which I thought, by Mr. Brown's description, was inverted. We parted, and I went home, a very silent companion to the gentleman who had given me a seat. Next day, impatient to see the effects of the separate condensation, I sent to Paisley and got some tin things made there, in completion of the notion that I had formed. I tried it as an air-pump, by making my steam vessel communicate with a tea-kettle, a condenser, and a glass receiver. In less than two minutes I rarefied the air in a pretty large receiver more than twenty times. I could go no farther in this process, because my pump for taking out the air from my condenser was too large, and not tight enough; but I saw that when applied to the mere purpose of taking out the air generated from the water, the vacuum might be made almost complete. I saw, too, (in consequence of a conversation the preceding day with Mr. Watt about the eduction-pipe in Beighton's engine,) that a long suck-pipe, or syphon, would take off all the water. In short, I had no doubt that Mr. Watt had really made a perfect steam-engine.

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"I think it was the middle of winter before I saw Mr. Watt. When we met, he most frankly told me all his contrivance, and I took care to receive it all as perfectly new to me, that I might not commit Mr. Brown. I remember well, that when he complained of the great power expended in working pumps sufficiently large to exhaust a condenser even of moderate size, (because they must do it at one stroke against the whole pressure of the atmosphere,) I mentioned the observation that I had formerly made to him on the eduction-pipe of Beighton's engine, and the contrivance which I would deduce from it for clearing the condenser of water. Mr. Watt said, 'O man, do you imagine me so dull as not to have thought on that long ago? But I could give you many reasons why it will not answer so well as a pump. I wish I could as quickly get quit of the air as of the water, without a pump. I don't despair even of this.' He now informed me of many curious properties of steam relative to its heat and elasticity, explained his methods of condensation, and mentioned some remarkable facts relative to this subject, which pass to this day before the eyes of everybody, without being noticed or understood by hundreds who call themselves engineers and builders of steam-engines.

"After this time my meetings with Mr. Watt were less frequent. He was much from home, working with his engine, and I was now obliged to devote my whole attention to another subject. Dr. Black, my preceptor in chemistry, was now removed to Edinburgh; and, by his very unmerited recommendation, the University of Glasgow placed me in the chemical chair which he had just quitted. Frightened by my own good fortune, I was obliged to strain every nerve to do some credit to so partial a recommendation, and I was obliged to relinquish all other occupations of my thoughts. But I had now learned all the principles of Mr. Watt's invention, though I had never seen either his engine or any model or drawing of it. I knew of his employing steam in place of the atmosphere to press forward his piston, although it was long ere I knew the way in which he introduced it. I thought he simply admitted it from the surrounding case by the open mouth of the cylinder; and it was not till I was in St. Petersburgh that I learned that he also introduced it (without a steam-case) by a pipe. This, however, was a *natural* part of the leading thought, and, indeed, was practised by him in his very first experiment.

"In this experiment, (which was made with a common anatomist's great injection-syringe for a cylinder,) the piston-rod passed through a collar of leathers in the cover of the cylinder, and the steam was admitted through another aperture in the same cover, and it escaped into the condenser by a similar aperture in a cover on the other end of the cylinder. Long after this I found that the little apparatus which I saw on his knee, and which he shoved under the table with his foot, was the condenser in this first experiment. I discovered that I had not comprehended the whole contrivance so completely as I imagined. But though I was ashamed of my ignorance, my vanity would not let me acknowledge it, and I took circuitous ways of learning more exactly the precise state of the engine. I was living in Edinburgh during the summer of 1767, near Dr. Black, in order to prepare myself for my arduous task, and in my conversations with Dr. Black I frequently introduced Watt's steam-engine. I one day asked him why Mr. Watt never thought of impelling the piston by steam much stronger than common steam, mentioning the way in which I could introduce and manage it. He then corrected me in some parts of my proposed construction, and described Mr. Watt's with accuracy, and bade me reflect on the enormous size and strength which must be given to the boiler, and the expense of fuel in supplying steam so dense and so hot. All this I had thought on already, and only wanted to learn what he had just now told me, and now I am fully entitled to say that, in the summer of 1767, the whole contrivance was perfect in Mr. Watt's mind, although he had neither executed the double stroke, nor that most beautiful contrivance of cutting off the steam before the piston reaches the bottom of the cylinder; a contrivance which in a moment fits the engine, however great and powerful, to any the most trifling task, and makes it more manageable than any other engine whatever that is not immediately actuated by the hand of man. Indeed, any person who deserves the name of engineer must see, and, if he speak from the conviction of his conscience, must acknowledge that the whole contrivance was perfect in Mr. Watt's mind in his very first trial.

"During the two following winters, notwithstanding Mr. Vatt's frequent absence from Glasgow, and my constant occupaon with my chemical lectures, I had many opportunities of conersing with him, and learned all his difficulties and embarrassients. He struggled long to condense with sufficient rapidity ithout injection, and exhibited many beautiful specimens of inenuity and fertility of resource. Many pretty schemes occurred) him for a rotatory engine. Some of these I am sorry to find iat he has neglected. I am confident of their complete success, nd though I agree with him in thinking that his engine with a ouble stroke is superior to them all, I should have been glad that hey had been executed, because they would have given a most rilliant specimen of his wonderful ingenuity and of his knowldge; for, indeed, the management of steam to perfection is the mployment of an accomplished philosopher.

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"During my residence in Glasgow I was in habits of coninual intimacy with Mr. Watt. All who knew him know that it s his greatest pleasure to communicate his knowledge to those vho have a relish for it. I have reason to think that he never, rom any kind of jealousy, concealed anything from me. From he day that he—I may almost say *we*—began to play with the College model, I knew almost every step of his thoughts; he was confined to his business; I was more at large, and going about the College. I ransacked the libraries for every book that he wanted, and every quotation that he met with made him impatient till he got at the original. I saw every book that he got by any other channel besides the public libraries. So I may safely say that I knew the whole extent of his reading. Our abode was too far out of the circle of business for allowing us to be informed of the numberless projects that are every day born and buried in this busy country. I can say, with great confidence, that nothing ever occurred to Mr. Watt, either by reading or information, of his leading principle, of a steam-vessel perpetually and universally hot. All the other contrivances, of separate condenser,—

air and water-pumps,—amalgam, or rosins, or fats for keeping the piston air-tight,—are but so many emanations from this first thought; and I will venture to say they all came into his mind in succession, and nearly in the order I have stated, after he said to himself, 'Let me make an engine, working by a piston, in which the cylinder shall be continually hot and perfectly dry.' I will venture to say that in no book previous to that date is there any account or proposal of such a thing, if we except some attempts to put the steam-vessel of Worcester's or Savery's engine in this predicament, by means of a travelling mass of oil or air, which was to be interposed between the steam and the water that was to be raised. Of these, Mr. Watt and I had some very imperfect account; but they never interested him, because the very nature of the operation made it impossible to do anything more than approximate to the desired object.

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"I must say, further, that the thought was wholly Mr. Watt's. For this I have every authority that can be wished for. I am certain that when I went out of town in (May, I think) 1765, he had not thought of the method of keeping the cylinder hot, and I am as certain that a fortnight after he had completed it, and confirmed it by experiment. Dr. Black, the first philosophical chemist of his time, and the most scrupulous man upon earth with respect to claims of originality, gave this to Mr. Watt in the most unqualified terms, the first time I saw him after I had learned it from Mr. Brown, and long before I saw Mr. Watt and got it more distinctly from himself." * * *

CHAPTER VII.

MR. WATT'S NARRATIVE OF THE INVENTIONS DESCRIBED IN HIS SPECIFICATION OF 1769, GIVEN IN HIS NOTES ON ROBISON—FURTHER ANECDOTES OF HIS INVENTION OF THE SEPARATE CONDENSER—HIS NARRATIVE ENTITLED "A PLAIN STORY."

THE account given by Mr. Watt himself, in his Notes on Professor Robison's Dissertation on Steam-engines,* is as follows :—

"My attention was first directed, in the year 1759, to the subject of steam-engines, by the late Dr. Robison, then a student in the University of Glasgow, and nearly of my own age. He at that time threw out an idea of applying the power of the steam-engine to the moving of wheel-carriages, and to other purposes, but the scheme was not matured, and was soon abandoned on his going abroad.

"About the year 1761 or 1762 I tried some experiments on the force of steam in a Papin's digester, and formed a species of steam-engine by fixing upon it a syringe, one-third of an inch diameter, with a solid piston, and furnished also with a cock to admit the steam from the digester, or shut it off at pleasure, as well as to open a communication from the inside of the syringe to the open air, by which the steam contained in the syringe might escape. When the communication between the digester and syringe was opened, the steam entered the syringe, and by its action upon the piston raised a considerable weight (15 lbs.) with which it was loaded. When this was raised as high as was thought proper, the communication with the digester was shut, and that with the atmosphere opened; the steam then made its escape, and the weight descended. The operations were repeated, and, though in this experiment the cock was turned by hand, it was easy to see how it could be done by the machine itself, and to make it work with perfect regularity. But I soon relinquished the idea of constructing an engine upon its principle, from being sensible it would be liable to some of the objections against Savery's engine, viz., the danger of bursting the boiler, and the difficulty of making the joints tight, and also that a great part of the power of the steam would be lost, because no vacuum was formed to assist the descent of the piston. I, however, described this engine in the fourth article of the specification of my patent of 1769; and again in the specification of another patent in the year 1784, together with a mode of applying it to the moving of wheel-carriages.

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* Robison's Mechanical Works, edited by Sir David Brewster.

"The attention necessary to the avocations of business prevented me from then prosecuting the subject further, but in the winter of 1763–4, having occasion to repair a model of Newcomen's engine belonging to the Natural Philosophy class of the University of Glasgow, my mind was again directed to it. At that period my knowledge was derived principally from Desaguliers, and partly from Belidor. I set about repairing it as a mere mechanician; and when that was done, and it was set to work, I was surprised to find that its boiler could not supply it with steam, though apparently quite large enough, (the cylinder of the model being two inches in diameter, and six inches stroke, and the boiler about nine inches diameter.) By blowing the fire it was made to take a few strokes, but required an enormous quantity of injection water, though it was very lightly loaded by the column of water in the pump. It soon occurred that this was caused by the little cylinder exposing a greater surface to condense the steam, than the cylinders of larger engines did in proportion to their respective contents. It was found that by shortening the column of water in the pump, the boiler could supply the cylinder with steam, and that the engine would work regularly with a moderate quantity of injection. It now appeare that the cylinder of the model, being of brass, would conduct hea much better than the cast-iron cylinders of larger engines, (gen rally covered on the inside with a stony crust,) and that consider able advantage could be gained by making the cylinders of som substance that would receive and give out heat slowly. Of thes wood seemed to be the most likely, provided it should prove suf ficiently durable. A small engine was, therefore, constructed, with a cylinder six inches diameter, and twelve inches stroke, made of wood, soaked in linseed oil, and baked to dryness. With this engine many experiments were made, but it was soon found that the wooden cylinder was not likely to prove durable, and that the steam condensed in filling it still exceeded the proportion of that required for large engines, according to the statements of Desaguliers. It was also found that all attempts to pro ice a better exhaustion by throwing in more injection, caused a sproportionate waste of steam. On reflection, the cause of is seemed to be the boiling of water in vacuo at low heats, a scovery lately made by Dr. Cullen and some other philosophers, elow 100°, as I was then informed,) and consequently, at greater eats, the water in the cylinder would produce a steam which ould, in part, resist the pressure of the atmosphere.

"By experiments which I then tried upon the heats at which ater boils under several pressures greater than that of the at osphere, it appeared that when the heats proceeded in an arith etical, the elasticities proceeded in some geometrical ratio; and, y laying down a curve from my data, I ascertained the particu r one near enough for my purpose. It also appeared that any pproach to a vacuum could only be obtained by throwing in large uantities of injection, which would cool the cylinder so much as o require quantities of steam to heat it again, out of proportion o the power gained by the more perfect vacuum, and that the old ngineers had acted wisely in contenting themselves with loading he engine with only six or seven pounds on each square inch of he area of the piston. It being evident that there was a great error in Dr. Desaguliers' calculations of Mr. Beighton's experiments on the bulk of steam, a Florence flask, capable of containing about a pound of water, had about one ounce of distilled water put into it; a glass tube was fitted into its mouth, and the joining made tight by lapping that part of the tube with packthread, covered with glazier's putty. When the flask was set upright, the tube reached down near to the surface of the water, and in that position the whole was placed in a tin reflecting oven before a fire, until the water was wholly evaporated, which happened in about an hour, and might have been done sooner had I not wished the heat not much to exceed that of boiling water. As the air in the flask was heavier than the steam, the latter ascended to the top, and expelled the air through the tube. When the water was all evaporated, the oven and flask were removed from the fire, and a blast of cold air was directed against one side of the flask, to collect the condensed steam in one place. When all was cold, the tube was removed, the flask and its contents were weighed with care, and the flask being made hot, it was dried by blowing into it by bellows, and, when weighed again, was found to have lost rather more than four grains, estimated at 4⅓ grains. When the flask was filled with water, it was found to contain about 17¼ ounces avoirdupois of that fluid, which gave about 1800 for the expansion of water converted into steam of the heat of boiling water.

"This experiment was repeated with nearly the same result, and in order to ascertain whether the flask had been wholly filled with steam, a similar quantity of water was for the third time evaporated, and, while the flask was still cold, it was placed inverted, with its mouth (contracted by the tube) immersed in a vessel of water, which it sucked in as it cooled, until in the temperature of the atmosphere it was filled to within half an ounce measure of water. In the contrivance of this experiment I was assisted by Dr. Black. In Dr. Robison's edition of Dr. Black's lectures, vol. i., p. 147, the latter hints at some experiments upon this subject, as made by *him*, but I have no knowledge of any except those which I made myself.

"In repetitions of this experiment at a later date, I simplified the apparatus by omitting the tube and laying the flask upon its side in the oven, partly closing its mouth by a cork, having a notch on one side, and otherwise proceeding as has been mentioned.

"I do not consider these experiments as extremely accurate, the only scale-beam of a proper size which I had then at my command not being very sensible, and the bulk of the steam being liable to be influenced by the heat to which it is exposed, which, in the way described, is not easily regulated or ascertained; but, from my experience in actual practice, I esteem the expansion to be rather more than I have computed.

"A boiler was constructed which showed, by inspection, the quantity of water evaporated in any given time, and thereby ascertained the quantity of steam used in every stroke by the engine, which I found to be several times the full of the cylinder. Astonished at the quantity of water required for the injection, and the great heat it had acquired from the small quantity of water in the form of steam which had been used in filling the cylinder, and thinking I had made some mistake, the following experiment was tried:—A glass tube was bent at right angles; one end was inserted horizontally into the spout of a tea-kettle, and the other part was immersed perpendicularly in well-water contained in a cylindric glass vessel, and steam was made to pass through it until it ceased to be condensed, and the water in the glass vessel was become nearly boiling hot. The water in the glass vessel was then found to have gained an addition of about one-sixth part from the condensed steam. Consequently, water converted into steam can heat about six times its own weight of well-water to 212°, or till it can condense no more steam. Being struck with this remarkable fact, and not understanding the reason of it, I mentioned it to my friend Dr. Black, who then explained to me his doctrine of latent heat, which he had taught for some time before this period, (summer 1764,) but having myself been occupied with the pursuits of business, if I had heard of it, I had not attended to it, when I thus stumbled upon one of the material facts by which that beautiful theory is supported.

"On reflecting further I perceived that, in order to make the best use of steam, it was necessary—first, that the cylinder should be maintained always as hot as the steam which entered it; and, secondly, that when the steam was condensed, the water of which it was composed, and the injection itself, should be cooled down to 100°, or lower, where that was possible. The means of accomplishing these points did not immediately present themselves, but early in 1765 it occurred to me, that if a communication were opened between a cylinder containing steam and another vessel which was exhausted of air and other fluids, the steam, as an elastic fluid, would immediately rush into the empty vessel, and continue so to do until it had established an equilibrium, and if that vessel were kept very cool by an injection, or otherwise, more steam would continue to enter until the whole was condensed. But both the vessels being exhausted, or nearly so, how were the injection-water, the air which would enter with it, and the condensed steam, to be got out? This I proposed, in my own mind, to perform in two ways. One was, by adapting to the second vessel a pipe, reaching downwards more than 34 feet, by which the water would descend, (a column of that length overbalancing the atmosphere,) and by extracting the air by means of a pump.

"The second method was by employing a pump, or pumps, to extract both the air and the water, which would be applicable in all places, and essential in those cases where there was no well or pit.

"This latter method was the one I then preferred, and is the only one I afterwards continued to use.

"In Newcomen's engine the piston is kept tight by water, which could not be applicable in this new method; as, if any of it entered into a partially exhausted and hot cylinder, it would boil, and prevent the production of a vacuum, and would also cool the cylinder by its evaporation during the descent of the piston. I proposed to remedy this defect by employing wax, tallow, or other grease, to lubricate and keep the piston tight. It next occurred to me that, the mouth of the cylinder being open, the air which opened to act on the piston would cool the cylinder, and condense some steam on again filling it. I therefore proposed to put an air-tight cover upon the cylinder, with a hole and stuffing-box for the piston to slide through, and to admit steam above the piston to act upon it, instead of the atmosphere. The piston-rod sliding through a stuffing-box was new in steam-engines; it was not necessary in Newcomen's engine, as the mouth of the cylinder was open, and the piston-rod was square and very clumsy. The fitting the piston-rod to the piston by a cone was an after improvement of mine, (about 1774.) There still remained another source of the destruction of steam, the cooling of the cylinder by the external air, which would produce an internal condensation whenever steam entered it, and which would be repeated every stroke; this I proposed to remedy by an external cylinder, containing steam, surrounded by another of wood, or of some other substance which would conduct heat slowly.

"When once the idea of the separate condensation was started, all these improvements followed as corollaries in quick succession, so that in the course of one or two days the invention was thus far complete in my mind, and I immediately set about an experiment to verify it practically. I took a large brass syringe, 1¾ inches diameter and 10 inches long, made a cover and bottom to it of tin-plate, with a pipe to convey steam to both ends of the cylinder from the boiler; another pipe to convey steam from the upper end to the condenser, (for, to save apparatus, I inverted the cylinder;) I drilled a hole longitudinally through the axis of the stem of the piston, and fixed a valve at its lower end, to permit the water, which was produced by the condensed steam on first filling the cylinder, to issue. The condenser used upon this occasion consisted of two pipes of thin tin-plate, ten or twelve inches long, and about one-sixth inch diameter, standing perpendicular, and communicating at top with a short horizontal pipe of large diameter, having an aperture on its upper side, which was shut by a valve opening upwards. These pipes were joined at bottom to another perpendicular pipe of about an inch diameter, which served for the air and water-pump, and both the condensing pipes and the air-pump were placed in a small cistern filled with cold water. This construction of the condenser was employed from knowing that heat penetrated thin plates of metal very quickly, and considering that if no injection was thrown into an exhausted vessel, there would be only the water of which the steam had been composed, and the air which entered with the steam, or through the leaks, to extract.

"The steam-pipe was adjusted to a small boiler. When steam was produced, it was admitted into the cylinder, and soon issued through the perforation of the rod, and at the valve of the condenser. When it was judged that the air was expelled, the steam-cock was shut, and the air-pump piston-rod was drawn up, which leaving the small pipes of the condenser in a state of vacuum, the steam entered them and was condensed. The piston of the cylinder immediately rose, and lifted a weight of about 18 lbs., which was hung to the lower end of the piston-rod. The exhaustion-cock was shut, the steam was readmitted into the cylinder, and the operation was repeated; the quantity of steam consumed, and the weights it could raise, were observed, and, excepting the non-application of the steam-case and external covering, the invention was complete, in so far as regarded the savings of steam and fuel. A large model, with an outer cylinder and wooden case, was immediately constructed, and the experiments made with it served to verify the expectations I had formed, and to place the advantage of the invention beyond the reach of doubt. It was found convenient afterwards to change the pipe-condenser for an empty vessel, generally of a cylindrical form, into which an injection played, and, in consequence of there being more water and air to extract, to enlarge the air-pump.

"The change was made because, in order to procure a surface sufficiently extensive to condense the steam of a large engine, the pipe-condenser would require to be very voluminous, and because the bad water with which engines are frequently supplied would crust over the thin plates, and prevent their conveying the heat sufficiently quick. The cylinders were also placed with their mouths upwards, and furnished with a working-beam and other apparatus, as was usual in the ancient engines; the inversion of the cylinder, or rather of the piston-rod, in the model, being only an expedient to try more easily the new invention, and being subject to many objections in large engines.

"In 1768 I applied for letters patent for my 'Methods of Lessening the Consumption of Steam, and, consequently, of Fuel, in Fire-Engines,' which passed the seals in January, 1769; and my Specification was enrolled in Chancery in April following."

Mr. John Hart, an ingenious tradesman of Glasgow, who was a native of Borrowstoness, and, together with his brother Robert, already mentioned, was distinguished by a predilection for the practical arts connected with science, has related that Mr. Watt frequently conversed with him on subjects of mechanical interest, and that being asked by him, in 1817, whether he recollected how the first idea of his great discovery came into his mind, he replied, "O yes, perfectly. One Sunday afternoon I had gone to take a walk in the Green of Glasgow, and when about half way between the Herd's House and Arn's Well, my thoughts having been naturally turned to the experiments I had been engaged in for saving heat in the cylinder, *at that part of the road* the idea occurred to me, that, as steam was an elastic vapour, it would expand, and rush into a previously exhausted space; and that, if I were to produce a vacuum in a separate vessel, and open a communication between the steam in the cylinder and the exhausted vessel, such would be the consequence."

Without dwelling on the particular scenes of these minute recollections, which, however, may in future interest the local topographer and antiquary, we do not fear being accused of undue repetition if we lay before the reader a more careful history, also given by Mr. Watt, of the origin and early progress of his inventions, so far as they were specified in relation to his first patent. This interesting document was prepared by him in 1796, as a general answer to the objections which his opponents, in the litigation already referred to, raised to the specification. Expressed in language both precise and clear, it was originally intended for the information of counsel, and, through them, of the Court, and was, by its unassuming author, with characteristic simplicity, entitled—

A Plain Story.

"W. found that a well-made brass model of Newcomen's engine consumed quantities of steam and fuel out of all reasonable or direct proportion with larger engines. He consulted Desagulier's 'Natural Philosophy,' and Belidor's 'Architecture Hydraulique,' the only books from which he could hope for information. He found that both of them reasoned learnedly, but by no means satisfactorily; and that Desaguliers had committed a very gross arithmetical error in calculating the bulk of steam from the water evaporated in a common steam-engine; which being rectified, it appeared next that his data, or assumed facts, were false. By a simple experiment, W. found what was the real bulk of water converted into steam; and from his friend Dr. Black he learned what was the heat absorbed and rendered latent by the conversion of water into steam, which the Doctor then publicly taught, and had done for some years. Experiments had been made long before by Dr. Cullen, Mr. John Robison, and others, in public classes, which proved that water, when placed in an exhausted receiver, boiled, and was converted into steam at the heat of 70° or 80° of Fahrenheit's thermometer, while it was well known that under the pressure of the atmosphere it required 212° of heat to make it boil, and emit steam capable of displacing the air. It was evident, that, under intermediate pressures, intermediate degrees of heat would be required to make it boil, and that in the steam-engine more or less cold water must be thrown in according to the degree of exhaustion which might be required; or, in other words, according to the number of pounds per inch the engine was loaded to.

"Newcomen's and Savery's engines existed; the latter were in general laid aside, on several accounts, but the principal one seems to have been that the cold water, the raising of which formed the effect of the engine, entered the steam-vessel itself, which in general was not a cylinder, but was of an oval or egg form; and, by cooling it, destroyed a great quantity of steam when it came next to be filled, which Desaguliers expressly notices. This engine, however, had an injection of cold water, to commence the condensation of steam, and Savery seems to have been the inventor of that valuable article;* but he also seems in some cases to have condensed the steam by pouring cold water on the outside of his copper steam-vessel.

"In Newcomen's engine the steam-vessel was a cylinder, or so meant to be. A piston was suspended, moveable in that cylinder; this piston hung by chains to the arch of a strong double-ended lever like a scale-beam, to the other end of which the rods which wrought the pumps were suspended in the like manner. The steam was admitted from a covered boiler, through a pipe, into the cylinder below the piston; the air was blown out by the steam at a pipe near the bottom of a cylinder, called the *snift*. The passage from the boiler was shut; cold water was spouted or injected into the cylinder from a cistern placed higher; the steam was thus condensed or rendered less elastic; the other end or mouth of the cylinder being open; the pressure of the atmosphere, not being resisted by an equally elastic fluid within, or under the piston, weighed upon the latter and caused it to descend, which, by means of the lever, drew up the pump-rods and raised the water. The injection-cock or valve was then shut, the steam-regulator or valve was opened, steam was readmitted, the equilibrium of pressure upon the upper and under sides of the piston was restored, and the superior weight of the pump-rods, by means of the great lever or working-beam, drew the piston to the top of the cylinder, and the operation recommenced. When the piston was at the bottom of the cylinder, the air which entered with the steam and with the injection water was blown out at the snift, and the hot water left in the cylinder was expelled through another pipe, called the *eduction-pipe,* which proceeded from the bottom of the cylinder, several feet downwards, and its lower end stood in a cistern of water, and was furnished with a valve to prevent regress.

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* Ascribed, however, by Desaguliers, vol. ii. p. 533, to Newcomen and Cawley.

"The steam-valve and the injection-cock were opened and shut by certain mechanism called working gear, which was put in motion by means of pegs in a piece of wood which was hung to and moved with the working beam, and was called the plug-tree.

"In order to supply the engine with cold water, it wrought a pump called a jack-head pump, which was shut at top by an iron cover, and its pump-rod wrought through a collar of oakum, which permitted the rod to slide up and down, while it precluded the exit of the water, which was raised to a greater height through a side branch turned upwards.

"Thus the latent heat of steam was discovered and published by Dr. Black; the boiling of water *in vacuo,* at low degrees of heat, was discovered and published by Dr. Cullen, Mr. Robison, and several others.

"The elastic powers of steam were known to Hero of Alexandria, and to many ancient writers. The steam-engine was invented by the Marquis of Worcester, Savery, Papin, and Newcomen.

"The means of confining steam, and the making valves, cocks, and regulators, were known to all of them. Pumps for drawing both air and water out of vessels or reservoirs were well known to everybody. An air-pump, with a piston-rod *moving through a collar,* was invented and published by Mr. Smeaton; and the same method, even before him, was commonly used in the jack-head pumps of common steam-engines, and in other machines; (this relates to the piston-rod of the cylinder; for, in respect to the air-pump, it is not necessary, though convenient, that it be shut at top.)

"A cylinder and moveable piston were used in Newcomen's engine; so were the working beam and working gear, or machinery for opening and shutting the valves and cocks.

"The steam was condensed by a spout of cold water in Savery's and Newcomen's engines; and, as it is said in Desaguliers, cold water was poured on the outside of the steam-vessels for the same purpose. Everybody knew that cold bodies of all kinds condensed steam when they came in contact with it. There were pipes in all those engines which admitted the steam from the boiler, and cocks or valves which shut it out from that vessel; and in Newcomen's engine there was a pipe which conveyed away the hot water, and a valve which prevented its regress.

"The diameters of those pipes, which admitted the steam and let out the injection-water, had been ascertained sufficiently near. The size and form of boilers, which answered sufficiently well, had also been ascertained.

"Of all those things, Watt must say, '*Non ea nostra voco.*' The things that are his remain to be told.

"He found, that by the application of the knowledge which has been mentioned, that the cause of the great consumption of fuel was, that the cylinder being cooled by the injection-water, that vessel *must* condense a large quantity of steam whenever it was attempted to be again filled with steam; that the vacuum could not approach to perfection without the steam was cooled below 100°; and that such cooling would increase the evil complained of in a fourfold or greater ratio, because the penetration of the heat or cold into the cylinder would be as the squares of the differences of the heat between that vessel and the steam. How was this to be avoided?

"He tried to make the cylinders of wood or other materials which conduct heat slowly, but he could not prevent the steam from coming into contact with the comparatively cold water which remained in the bottom of the cylinder, and which must be expelled by the steam; besides his wooden cylinders did not seem likely to be of long duration. In such-like experiments, he spent much time, and more money than was suitable to his circumstances, yet he made no advances towards a beneficial discovery. But the matter having got firm hold of his mind, and his circumstances obliging him to make exertions to regain what he had spent, he turned the matter over in every shape, and laid it down as an axiom,—*that to make a perfect steam-engine, it was necessary that the cylinder should be always as hot as the steam which entered it, and that the steam should be cooled down below* 100° *in order to exert its full powers.* The gain by such construction would be double:—first, no steam would be condensed on entering the cylinder; and secondly, the power exerted would be greater as the steam was more cooled. The *postulata*, however, seemed to him incompatible, and he continued to grope in the dark, misled by many an *ignis fatuus*, till he considered that steam being an elastic fluid, it must follow the law of its kind; and that if there were two vessels, A and B, of equal or other dimensions, the one, A, filled with steam, and the other, B, exhausted, if a communication were opened between those vessels, the steam would rush from the full one into the empty one, and they would both remain half exhausted, (if the vessels were equal in size,) or be filled with steam of half the density. If, then, into the second vessel, B, an injection of cold water were made, or cold water applied to its outside in sufficient quantity, the portion of steam which it contained would be condensed or reduced to water; and by the same law of nature that had operated before, more steam would issue from A into B until the whole was condensed, and nearly a perfect vacuum established in both vessels; yet as the cold water had not entered or touched A, that vessel would still retain its heat.

"This idea once started, the rest immediately occurred. The vessel A being supposed to be the cylinder, B would be the vessel called now the condenser; the water, air, &c., accumulated in B, he immediately saw could be discharged or drawn out by means of a pump, or the water might be let run out by a pipe more than 34 feet long, going downwards, and the air might in that case be expelled at a valve by filling B with water, provided the descending eduction-pipe were shut meanwhile. On the whole, however, he preferred the pump. Another difficulty appeared, which was the making the piston tight. That could not be done with water, as in Newcomen's engines; for that might get in and evaporate, and produce steam. He therefore thought of wax, oil, and similar substances, as substitutes, knowing that they would not evaporate in the heat of boiling water; and, for greater security, he proposed to employ the steam itself as the acting power on the piston,

"The diameters of the pipes necessary to convey the steam into and out of the cylinder, he regulated from those in use. The size of the condenser he assumed at random, as he did that of the air-pump, which it was evident must be larger than was necessary to contain the water and probable quantity of air. All this passed in his mind in the course of a few hours; and in a few days he had a model at work, with an inverted cylinder, which answered his expectations, and was, as far as he remembers, equal in its properties of saving steam and fuel to any he has made since, though in point of mechanism much inferior. Very simple cocks were employed as regulators or steam-valves, and his air-pump and condenser were of tin-plate. His cylinder, however, was good, and of brass [about] 2 inches diameter, and a foot long; the cocks were turned by hand, instead of being wrought by the engine.

"If Mr. W. is thought worthy of credit in this matter, and the facts are consequently allowed, where was the mighty difficulty of putting the invention in execution from still fewer data than he has set forth in his specification? He is not so presumptuous as to think that there were not, and are not, numbers of mechanics in this nation, who, from the same or even fewer hints, would have completed a better engine than he did. Mr. Bramah has proved* that he could, and W. is inclined to believe him. But W. does not pretend that *any body* could have done it without *thinking* upon it, nor without much previous knowledge and some experience of similar things.

"Had W. been content with the mechanism of steam-engines as they then stood, his machine might soon have been brought before the public; but his mind ran upon making engines *cheap* as well as *good*, and he had a great hankering after inverted cylinders and other modifications of his invention, which his want of experience in the practice of mechanics in great, flattered him would prove more commodious than his matured experience has shown them to be. He tried, therefore, too many fruitless experiments on such variations. He wanted experience in the construction of large machines; that he endeavoured to acquire; but experimental knowledge is of slow growth, and with all his ingenuity, *so much boasted to his prejudice*, he was concerned in making some very indifferent common engines. Other avocations, to him necessary, obliged him to turn his attention from the subject till he obtained the patent, so that at that time he had made no advances in the improvement of the mechanism. He therefore thought it proper to specify only what was his invention, and to leave any mechanical improvements he might make, to be secured by other patents, if worthy of them.

"His idea, then, was to apply his invention to the steam-engines as they existed. For this purpose there was nothing else necessary than to shut up the snift, to apply a regulator or valve to the opening of the eduction-pipe within the cylinder, an air-pump to the outer end of that pipe, and to inject into the upper end of the eduction-pipe. If, at the same time, the cylinder was defended from the cold of the atmosphere, the engine would thus be complete, if the weight of the atmosphere were to be employed as the acting power; for all the regulators could be easily opened and shut by the then existing contrivances, and the air-pump rod could be suspended from the working beam.

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* *i. e.* Given it in evidence.

"If, however, the engine was wanted to receive all the advantages of the invention, the cylinder was to be placed in a case containing steam, with access for that fluid to the upper side of the piston, so that it might act upon it as the atmosphere acted in common engines, or in the case just stated. And in this latter manner were the engines made which he constructed in the beginning of the business; that is to say, the cylinders were fixed in a case containing steam, with which fluid they were wholly surrounded; and, their mouths being open within the case, the steam had always access to the upper side of the piston, and was admitted to the part below the piston only when the piston was rising. The opening from the cylinder into the eduction-pipe was shut by a valve while the piston was rising, but when it was required to descend, the valve was opened. Those valves were of the sliding kind used in Newcomen's engines. The injection was made into the eduction-pipe; and the air-pumps, which drew out the water as well as the air, were fixed to the bottom of the eduction-pipe, which had a valve to prevent regress as usual. There was sometimes one pump, and sometimes there were two or three, as circumstances or the fancy of the moment directed. The working beams and working gear were made in the usual manner, or nearly so; and in cases where there were boilers fixed for the common engine, which was superseded, they were used without alteration.

"These engines, then, differed in nothing from the ancient ones, except in the application of W.'s principles, as set forth in his specification.

"It was found that the external cylinder, or steam-case, was very expensive. The method of covering *the cylinder itself* with a lid or cover, (which had been used in some of the models,) and conveying the steam to the lower end of the cylinder by a pipe, was adopted, and a less expensive method of applying the envelope of steam was used. Other kinds of regulators were invented, and the whole mechanism of the engine was gradually improved, and these improvements have been progressive for the last twenty-one years. Some of them W. has secured by other patents, but many of the most essential he has left free, and by means of them Newcomen's engines have been improved to his loss.

"It will now, it is hoped, appear to the candid that W. has not wilfully concealed his invention by a false specification, but has set forth the nature of the same, and the means of performing it. He has told what he had invented; and it could not have been expected that he should have described mechanism already known to all practitioners, or not then invented.

"W.'s invention is merely a contrivance to prevent cooling the cylinder, and to make the vacuum more perfect by *condensing the steam in a vessel distinct from the cylinder itself;* this is the nature of the invention. The means of keeping the cylinder warm,—the substitution of the powers of steam for those of the atmosphere,—of grease, &c., in place of water to keep the piston tight,—and the drawing out the air, &c., by means of pumps, are merely aids in performing the principal object. This ought to be kept in view in judging of the specification; also that W. supposed it to be addressed to mechanics and philosophers, and not to the ignorant."

CHAPTER VIII.

DR. BLACK'S AND PROFESSOR ROBISON'S ACCOUNT OF MR. WATT'S INTRODUCTION TO DR. ROEBUCK—ENTIRE ORIGINALITY OF MR WATT'S INVENTION—CONFIRMED BY DR. ROEBUCK—WILCKE'S AIR-PUMP ACTING BY THE CONDENSATION OF STEAM—SUBSEQUENT TO MR. WATT'S INVENTION OF THE SEPARATE CONDENSER—HUMPHRY GAINSBOROUGH.

WITH regard to the model of Newcomen's engine belonging to the College of Glasgow, and which has attained so great a celebrity by the results which it was instrumental in producing, we find two entries in the records of that University: the first is as follows:—"University meeting, 25th June, 1760. Mr. Anderson is allowed to lay out a sum, not exceeding two pounds sterling, to recover the steam-engine from Mr. Sisson, instrument-maker at London."

Mr. John Anderson in 1757 succeeded Dr. Dick as Professor of Natural Philosophy in the College.

The next entry concerning the model, in the same records, appears to be this:—"University meeting, 10th June, 1766. An account was given in by Mr. James Watt for repairing and altering the steam-engine, with copper pipes and cisterns, amounting to 5*l.* 11*s.* The said machine being the property of the College, and having been in such a situation that it did not answer the end for which it was made, the Principal is appointed to grant a precept for payment of the said account, which is to be stated upon the fund for buying instruments to the College."

This, it will be remembered, was after the idea of the separate condenser had "occurred," which was "early in 1765;" and by the repairs and alterations of the "copper pipes and cisterns" of the machine, its fault of *not answering the end for which it was made*, had in all probability been effectually corrected. That interesting little model, as altered by the hand of Watt, and preserved in all safety and honour within the precincts of its ancient birth-place, had been appropriately placed beside the noble statue of the Engineer, in the Hunterian Museum. But on revisiting the College of Glasgow in January, 1854, we found that it had been placed among the apparatus attached to the Natural Philosophy Lecture-room, where, it was alleged, it had dwelt nearly a century ago.

None of the different accounts which thus remain to us of the date of this, Mr. Watt's greatest invention, fix the precise day on which, to use Dr. Black's happy expression, "this capital improvement flashed on his mind at once, and filled it with rapture." According to Robison's recollection, thirty-one years afterwards, it was somewhere about 1765. Dr. Black, writing after the same interval of time, states it as having been "in the beginning of the year 1765." Mr. Watt himself, in his notes on Robison, says "early in 1765;" and the nearest approximation we can make, from other documentary evidence, to any more precise date, is, that it must have been previous to the 29th of April in that year, as on that day Mr. Watt writes to his friend Dr. Lind, "I have now almost a certainty of the *facturum* of the fire-engine, having determined the following particulars: the quantity of steam produced; the ultimatum of the *lever engine;* the quantity of steam destroyed by the cold of its cylinder; the quantity destroyed in mine: and if there is not some devil in the hedge, mine ought to raise water to 44 feet with the same quantity of steam that theirs does to 32, (supposing my cylinder as thick as theirs,) which I think I can demonstrate. I can now make a cylinder of 2 feet diameter and 3 feet high only a 40th of an inch thick, and strong enough to resist the atmosphere; *sed tace.* In short, I can think of nothing else but this machine. I hope to have the decisive trial before I see you. Write me to-morrow what you are about, and if any part of what you have to tell me concerns the fire-engine."

"His mind," says Dr. Black, "became now very much employed in contriving the machinery by which this improvement might be reduced to practice; and he soon planned it to such a degree that he thought he was ready to make an experiment on a large scale. But here he was stopped by the want of funds; and he found it necessary to associate himself with some person who had money and spirit for such an undertaking, and to participate with him the advantages which might be derived from this invention. He addressed himself to the late Dr. Roebuck, whose spirit for enterprise and improvement in arts was very well known, and the Doctor accordingly received with zeal the opportunity offered to him. A small engine was soon built in one of the offices of Kinneil House, near Borrowstoness, where various trials were made, and some difficulties surmounted, so as to give satisfaction.

"I must add that I was as much upon a footing of intimate friendship with Dr. Roebuck as with Mr. Watt. The Doctor, too, had no small degree of mechanical knowledge and ingenuity; and was well qualified to perceive and value the talents of Mr. Watt. He had also much experience in the use of common steam-engines, which he employed in working his colliery. He was withal ardent and sanguine in the pursuit of his undertakings, and was therefore a fortunate associate for Mr. Watt. Mr. Watt was a valetudinarian, more or less, ever since I knew him; and his mind was liable to be too much depressed by little cross accidents, or by the necessity of a greater expense than he had foreseen; whereas the Doctor was undaunted on such occasions, and roused Mr. Watt to disregard expense, and to double his exertions, until the difficulty was overcome. But Mr. Watt was the sole inventor of the capital improvement and contrivance above mentioned. I remember very well that it cost me several reasonings and conversations to inform the Doctor fully of the nature of steam, of the great quantity of heat, and, consequently, of fuel necessary to produce it, and of the importance, therefore, of preventing the waste of it."

"I was very unfortunate," says Robison, "in two visits I made to Glasgow during that summer; Mr. Watt being from home, once at Greenock, seeing his father, who was ill, and the other time on a survey for a canal. When I came to town for the winter, I found that Mr. Watt was again from home, and that he was deeply engaged with his engine. His situation in life made it imprudent to engage in great expenses, and he was obliged to look out for an associate. Most fortunately there was in the neighbourhood such a person as he wished,—Dr. Roebuck, a gentleman of very uncommon knowledge in all the branches of civil engineering, familiarly acquainted with the steam-engine, of which he employed several in his collieries, and deeply interested in this improvement. He was also well accustomed to great enterprises, of an undaunted spirit, not scared by difficulties, nor a niggard of expense. Such a man was indispensably necessary to one of Mr. Watt's character;—modest, timid, easily frightened by rubs and misgivings, and too apt to despond. I do not know who pointed him out to Mr. Watt. He was well acquainted with Mr. Watt's talents, and admired them. I believe the connection was very soon formed. Dr. Black and all Mr. Watt's friends were happy at seeing so fair a commencement. At this time I had not the pleasure of being known to Dr. Roebuck." * * * "I believe that Dr. Black was the chief means of forming the connection between Mr. Watt and Dr. Roebuck; and I recollect most distinctly his saying to me, that Watt would have some difficulty in managing Dr. Roebuck, who at that time had not become a complete convert to the doctrine of latent heat. Accordingly, it was so; and Mr. Watt was obliged to yield for some time to the Doctor's confidence in his own great experience. The Doctor thought to produce the condensation, with sufficient rapidity and accuracy, by a very extensive surface; and Mr. Watt knew that it also required a great quantity of water, or other matter, to receive the emerging heat. I know that these differences of opinion retarded the completion of the engine.

"But Dr. Roebuck had too much judgment not to see the conclusiveness of the experiments by which the doctrine of latent heat is established, and not to yield to their force; and everything went on at last to their mutual satisfaction. Dr. Roebuck knew Mr. Watt's talents, and most liberally praised them. His timidity, his disposition to despond when under unforeseen difficulties, and his painful anxiety and diffidence in himself, were frequently the subjects of friendly merriment at the Doctor's fireside; and I have often heard him say, that without his help, and even his instruction, on many points of the construction, Mr. Watt could never have gone on. I have even heard him mention some important, but subordinate parts of the engine, which were of his contrivance. But I never heard him lay the smallest claim to the leading thought of a hot and dry cylinder for the piston to work in, and, therefore, a separate condenser. I never knew him to call it 'my engine,' nor 'our engine,' but uniformly 'Watt's engine,' when he had occasion to speak of it as distinct from the *old* or *Newcomen's* engine. I remember Mrs. Roebuck saying one evening, 'Jamie is a queer lad, and without the Doctor his invention would have been lost; but Dr. Roebuck won't let it perish. I mention all these trifling things because I have often heard gentlemen living in the neighbourhood of Borrowstoness speak of this new project as Dr. Roebuck's, in which he was assisted by one Watt, from Glasgow. One gentleman in particular, Mr. Graham of Airth, insisted with me that Dr. Roebuck was the inventor. But one day Mr. Graham came home from Falkirk, where he had seen Dr. Roebuck, and engaged him in conversation on the subject. He told me that he now saw plainly that Mr. Watt was the sole author, and said that he would be at some pains to undeceive some gentlemen of the neighbourhood, who were of the opposite opinion. This was very natural. Dr. Roebuck was a gentleman of uncommon knowledge in everything of this kind, and considered as the first judge in all that country of all such matters; whereas Mr. Watt was an entire stranger.

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"I remember, also, that in 1774, or 1775,* after my return from Russia, I had some conversation with Dr. Roebuck. The Doctor spoke with some dissatisfaction of Boulton and Watt. They were now, he said, amassing fortunes from a project which his misfortunes had obliged him to cede to them. They seemed to have forgotten that he had suffered all the anxieties attending the infant project; he had run all the risk,—and the risk had been very great, both from the novelty of the thing, and from Mr. Watt's delicate health, and his timidity under difficulties; that without his continual encouragement and support, it never would have succeeded. He had ceded his right on very moderate terms, and he had expected some remembrance of this. In this disposition to repine at an opportunity which he had lost of benefiting himself, it would have been most natural for Dr. Roebuck to put a high value on any part that he had had in the discovery; and I listened with some anxiety to hear if he advanced any claim of this kind, for I knew that any such thing from Dr. Roebuck would be received with much deference. But I have the most distinct recollection that he made no claim whatever of this sort; but, on the contrary, spoke in the highest terms of Mr. Watt's ingenuity and inexhaustible resource of invention.

"The duties of my profession call my attention to a great variety of very interesting objects. Of all these, my favourite object is practical mechanics. I have, therefore, hunted everywhere for information, and my opportunities have been considerable. Understanding most of the languages of Europe, I have looked into almost every book which treats of such things; and, in particular, I have searched for every project in mechanics, description of machines, and schemes of public works. I can recollect but one trace of anything like a separate condenser of steam.

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* This date probably was given by Dr. R. in mistake for a later one, as Mr. Watt's Act of Parliament was obtained in May, 1775; after which, though in the same year, it was that he entered into partnership with Mr. Boulton. It was several years before the manufacture of the improved steam-engines, which only commenced in 1775, became in the least degree remunerative.

This is in a volume of the 'Commentarii de Rebus in Medicinâ et Scientiâ Naturali gestis;' I cannot now recollect the volume, and only remember that it is a late one; (indeed this whole work is of a date posterior to 1769). In this volume there is a short account given of an air-pump by M. Wilcke, of Upsal or Stockholm, precisely such as I made when I heard of Mr. Watt's contrivance. It is mentioned as a thing which the Reviewers had forgotten in its proper time, and they say, '*dudum fabricavit.*' I mentioned this about a year ago to Dr. Black, when we were speaking of some curious observations of M. Wilcke on the cloud which appears in the receiver of an air-pump when damp air is suddenly rarefied. The Doctor told me that, when he was yet in Glasgow, he had a pupil of the name of Williams, or Williamson, from the Mine College in Sweden; that this person was intimately acquainted in Dr. Roebuck's family, and, he believed, also with Mr. Watt; that he was in this country almost three years, and fully understood all his theory; and he had no doubt that Dr. Wilcke owed to him all that he had published on that subject. He thought it equally probable that this project of an air-pump had transpired in some of our conversations, it being a thing on which we put no value." * * *

The following is evidently the notice intended to be referred to by Dr. Robison, which we here translate from the Latin, in which language it is printed in the Transactions of the Royal Academy of Sciences of Sweden:—

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"3. John Charles Wilke, Lecturer on Experimental Philosophy, proposes *a new kind of air-pump*. He makes use of the well-known property which the steam of boiling water possesses, of so expanding itself as to drive out the air from any space which it fills. Instead, therefore, of that cylinder, in which, in common pumps, the sucker moves, he takes a metallic vessel, into which, by means of a tube, the steam of water, boiling over a fire, can ascend; by another aperture, the air contained in the vessel (which he calls a receiver) retires before the steam. The receiver is joined to a globe, on which a glass bell may be placed, as in common pumps; and those three apertures of the receiver, by which the steam enters, the air escapes, and the globe is connected with it, may be closed by valves or cocks. The last of them, up to this point, is kept shut. When the steam, ascending into the receiver, has sufficiently expelled the air, the cock by which the air had escaped is closed, and the receiver is surrounded with cold water. The steam, thus condensed, returns, in the form of drops, to the vessel whence it came; and the cock which, when open, had permitted it to rise, being now closed, a vacuum, to a great extent, is formed in the receiver. Then the cock by which it is joined to the globe, being opened, air will rush into it from the bell. This kind of exhaustion may be repeated, till there remains under the bell [no more than] a one hundred and thirtieth portion of the air, in the machine with which Mr. Wilke made his experiment, and which was by no means so perfect as it might be made by greater care. Even common air-pumps, as improved by Nollet, rarefy air about 300 times; (Wilke takes no notice of John Smeaton's pump, mentioned in the Philosophical Transactions, vol. xlvii. Art. 69, by which air is said to be rarefied 500 or even 1000 times) so that this one, a little better made, will easily equal their performance; but its principle is, that it will exhaust the air suddenly, not, as the common ones do, by degrees: (Nollet and others showed how a large receiver could be first emptied of air, and applied to the bell, so as to let the air from the latter suddenly rush into it.) 'But,' it is added, 'as it needs fire and water, its use is attended with some inconveniences.'" *

Dr. Robison is not quite accurate in saying that the whole of the 'Commentarii' are of a date posterior to 1769. The work was published in a series of thirty-seven volumes, commencing in

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* 'Kongl. Vetenskaps Academiens Handlingar för Aor 1769,' vol. xxx. &c., *i. e.*, Acta Academiæ Reg. Sc. Suecicæ, anni 1769, vol. xxx. (Trimestre primum,) printed in the 'Commentarii de Rebus in Scientiâ Naturali et Medicinâ gestis,' voluminis xviii. pars I. Lipsiæ, 1772.

1752, and ending in 1806; with three volumes of 'Supplementa,' 1763-96, and three of Indices, 1770-1793. But it is certain that the passage quoted above is of a date several years subsequent to Mr. Watt's invention of the separate condenser; and the circumstances through which it happened that Mr. Wilcke was even so early in possession of the idea of an air-pump, such as that described, are, no doubt, very well explained by Dr. Robison.

Although our readers may probably be of opinion that it does not require such notice, we may here advert to a story told in a recent Life of Gainsborough the artist,* concerning his brother Humphry.

"We may mention," says Mr. Fulcher, "that his experiments upon the steam-engine were far in advance of his time. Indeed, it was stated by his family and friends, that Watt owed to him one of his great and fundamental improvements, that of condensing the steam in a separate vessel. Certain it is, that Mr. Gainsborough had constructed a working-model of a steam-engine, to which his discoveries were applied, and that a stranger, evidently well acquainted with mechanics, and supposed to be connected with Watt as an engineer, was on a visit at Henley, and called upon him, to whom he unsuspectingly showed his model and explained its novelties. His relatives have assured the Author that such was the fact, and that the circumstance of having thus lost the credit of his discovery, made a deep and melancholy impression upon his mind. The truth of this statement receives also strong corroboration from the remarks of Thicknesse, who says,—'Mr. Gainsborough' (the painter) 'gave me, after the death of his clergyman brother, the model of his steam-engine; that engine alone would have furnished a fortune to all the Gainsboroughs and their descendants, had not that unsuspicious, good-hearted man, let a cunning, designing artist see it, and who surreptitiously carried it off in his mind's eye.' Watt obtained his first patent for performing condensation in a separate vessel from the cylinder, in

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* Life of Thomas Gainsborough, R.A., by the late George Williams Fulcher. Edited by his Son. London. 1856.

1769; it was renewed in 1775. Humphry Gainsborough died in 1776." *

But, fortunately, Mr. Fulcher's story is not original with him, nor is a test of its truth now to be applied to it for the first time.

Jabez Hornblower, who, after having been long employed as a stoker in Messrs. Boulton and Watt's manufactory at Soho, was, in the end of the last century, convicted of gross piracy of Mr. Watt's invention, employed a portion of the leisure which fell to his lot in the King's Bench Prison, in writing a first edition of the same fable, which was published in Gregory's Mechanics. Mr. Hornblower, however, with less caution than Mr. Fulcher, did not altogether evade the mention of any name or detail to authenticate his tale; but appealed, in proof of it, to a conversation said to have been held with Mr. Samuel More, the very respectable Secretary to the Society of Arts.

Now, in the trial of the cause, Boulton and Watt *v.* Bull, in the Common Pleas, 22nd June, 1793, Mr. More was, it happens, examined as a witness. He was asked, "You must have seen and known a vast number of machines of various kinds;—Did you ever meet with the application of those principles Mr. Watt has applied to the fire-engine before you knew Mr. Watt's engine?" And upon oath he answered, "My situation in life leads me to see a vast many mechanical contrivances, and my inclination leads me to look into them. I take it to be the most useful engine that has ever been brought forward by the mind of man; I have considered it attentively; *I do declare I never saw the principles laid down in Mr. Watt's specification either applied to the engine previous to his taking it up, nor ever read of any such thing whatever.*"

If it be true,—although of this we have no proof beyond Hornblower's assertion,—that Mr. More had inspected Mr. Humphry Gainsborough's "working-model" to which his precious

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* Fulcher, pp. 18, 19.

"discoveries" were "applied," this only makes his evidence in favour of the entire novelty as well as originality of Mr. Watt's steam-engine the more conclusive. Mr. Humphry Gainsborough's opinion of the value of his own machine, as compared with that of Watt, appears, no doubt, to have been tolerably good; for "Suppose," writes Mr. Boulton to Mr. Watt in 1775, "another ingenious man starts up with another new discovery that should prove to be seven times better than the common engine, whilst ours is only three times, what then becomes of all the fabric we have raised, and of the visionary profits? And let me tell you that there is a great probability of it, for there is a very ingenious man at Henley-upon-Thames, who asserts that he hath made such a discovery." The person here alluded to,—who would have been very ingenious indeed if the ratio of seven to three in favour of his steam-engine against that of Watt had only proved to be true! —was no doubt Gainsborough;—as in a subsequent letter, believed to have been written in 1776, Mr. Boulton talks of "Tubal-Cains, or Watts, or Dr. Fausts, or Gainsboroughs, arising with serpents like Moses', that devour all others.

CHAPTER IX.

HISTORY OF THE STEAM-ENGINE BEFORE THE TIME OF WATT—ÆOLIPILES—GERBERT—PORTA—RIVAULT—SOLOMON DE CAUS—MARQUIS OF WORCESTER—HIS 'CENTURY OF INVENTIONS'—QUESTION WHETHER HE EXECUTED HIS APPARATUS—HIS ACT OF PARLIAMENT—BEAUFORT MSS.—ROLLOCK'S "PANEGYRIC"—TRAVELS OF COSMO DE MEDICIS.

As we are now arrived at that important epoch of Mr. Watt's life when he made the first, the greatest, and the most prolific of all his mighty inventions connected with the steam-engine, it is necessary that we should give some explanation of the state in which he found that machine, as then employed in imperfectly draining some collieries and mines in Great Britain, although not otherwise made available in either this or any other country. Without a brief historical sketch, such as this renders necessary, many of our readers would find it difficult either to follow the steps by which Mr. Watt ascended in his successive inventions, to understand their importance, or to appreciate their beauty; and we venture to believe that it is possible to communicate all that is on the present occasion needful to be known on this part of our subject, without perplexing our narrative by details either very numerous or at all obscure.

The earliest instance of a machine in which steam was deliberately used to generate motion, is, it seems to be generally admitted, the Æolipile,—Æoli-pila, or ball of Æolus,—such as is delineated and described by Hero of Alexandria, in his Pneumatica, or Spiritalia,* about 120 B. C. This æolipile was a hollow ball of metal, moveable on external axes working in sockets, and fitted with one or more tubes issuing from it horizontally, closed at their ends, but with an opening in their sides. This ball being partially filled with water, and placed over a fire, the re-action of the steam, rushing with violence from those openings, caused it to revolve with more or less rapidity, according to the force of steam employed. The machine has been constructed of several forms, and has often served purposes of ingenious amusement. In point of practical utility, it is recommended by Branca, in his work entitled 'Le Machine,' published at Rome in 1629, to be used to produce a rotatory motion, by acting on the pinions of a wheel. It has also been employed instead of bellows, directing a strong current of steam on the fire, in place of a blast of air.

But the most singular details as to an instrument of this sort with which we have met, are given in the following passage, taken from Plot's Staffordshire:—"Yet there are many old customs in use within memory, of whose originals I could find no tolerable account, that possibly might commence as high as these times; such as the service due from the Lord of Essington in this county [Stafford] to the Lord of Hilton, about a mile distant, viz., that the Lord of the manor of Essington shall bring a goose every New-year's-day, and drive it round the fire in the hall at Hilton, at least three times, (which he is bound to doe as mean lord,) whil'st *Jack* of *Hilton* is blowing the fire. Now, *Jack* of *Hilton* is a hollow little image of brass of about 12 inches high, kneeling upon his left knee, and holding his right hand upon his head, * * * having a little hole in the place of the mouth, about the bigness of a great pin's head, and another in the back about $\frac{2}{3}$ of an inch diameter, at which last hole it is filled with water, it holding about 4 pints and $\frac{1}{4}$, which, when set to a strong fire, evaporates after the same manner as in an æolipile, and vents itself at the smaller hole at the mouth in a constant blast, blowing the fire so strongly that it is very audible, and makes a sensible impression in that part of the fire where the blast lights, as I found by experience, May the 26th, 1680." *

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* A curious treatise, which, along with his other works, is to be found in the Mathematici Veteres, Gr. et Lat., Par. 1693, fol.

William of Malmesbury describes as being preserved in the Cathedral of Rheims, among other proofs of the mechanical skill of Gerbert, (afterwards Pope Sylvester II., who died A.D. 1003,) a hydraulic organ, blown "by the violence of boiling water." †

Baptista Porta, a Neapolitan gentleman who devoted his life to researches in chemistry and natural philosophy, in which he displayed remarkable ingenuity, and distinguished himself by inventing the magic lantern, has left us an account, in a work published in 1601,‡ of some curious experiments on the power of steam, on its condensation, and on its relative bulk as compared with water. In one of them, a vacuum is distinctly formed by condensation, and water is forced up into it by the pressure of the atmosphere; and although this appears, both from his description, and from the rude wood-cut which accompanies it, to have been performed on the scale not of any large engine for raising water, but only of a small philosophical apparatus, still the novel principle is there clearly pointed out, and made available to any of his readers. In another experiment, a retort has its neck inserted in a cistern which is nearly filled with water; the water in the retort is then made to boil, and the steam, pressing on the water in the cistern, forces it up through a tube fixed in its lid.

David Rivault, Seigneur de Flurance, near Laval, in France, in a treatise on the Elements of Artillery, which he published in 1605, and of which a second edition, containing an additional fourth book, appeared in 1608, describes the power of steam in

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* Nat. Hist. of Staffordshire, by Robert Plot, LL.D., p. 433, edit. Oxford, 1686. At plate xxxiii. of that work there is an engraved likeness of *Jack*, to which we refer those of our readers who are curious in such matters.

† Willielm, Malmesbur. de gestis Regum Anglorum, Lib. ii.; inter Rer. Anglic. Script. ed. Lond. 1596, fol. 36, *verso*.

‡ Pneumaticorum libri tres: cum duobus curvilineorum elementorum (printed at Naples), 4to. It was translated into Italian, and published, also at Naples, with the title, 'I tre libri de' 'Spiritali,' 1606, 4to.

bursting a strong bomb-shell, partly filled with water, then tightly plugged, and set on a fire. But here, with a power of very great destructiveness, there is evidently a total want of any means of moderating, or almost of estimating, that dangerous force.

The contrivance described and figured by Solomon De Caus is as follows:—Take a strong hollow copper globe, with a cock near the top to admit water, and through the middle of the top a pipe fixed, with its lower end reaching nearly to the bottom of the globe, without quite touching it; fill the globe with water through the cock, close it firmly, (the pipe, however, remaining open,) and put it on the fire; then the heat, acting upon the globe, will make all the water ascend through the pipe.

The name next in the series of early "students of steam," is that of Edward, second Marquis of Worcester; in whose 'Century of Inventions,' first published in 1663, occur the following curious articles:—

"68. An admirable and most forcible way to drive up water by fire, not by drawing or sucking it upwards, for that must be, as the philosopher calleth it, *Intra sphaeram activitatis*, which is but at such a distance. But this way hath no bounder, if the vessels be strong enough; for I have taken a piece of a whole cannon, whereof the end was burst, and filled it three-quarters full of water. Stopping and scruing up the broken end, as also the touchhole, and making a constant fire under it, within 24 hours it burst and made a great crack. So that having a way to make my vessels, so that they are strengthened by the force within them, and the one to fill after the other, I have seen the water run like a constant fountaine-stream forty foot high; one vessel of water rarified by fire driveth up forty of cold water. And a man that tends the work is but to turn two cocks, that one vessel of water being consumed, another begins to force and re-fill with cold water, and so successively, the fire being tended and kept constant, which the selfsame person may likewise abundantly perform in the interim between the necessity of turning the said cocks."

"98. An engine so contrived, that working the *primum mobile* forward or backward, upward or downward, circularly or corner-wise, to and fro, streight, upright or downright, yet the pretended operation continueth, and advanceth none of the motions above-mentioned, hindering, much less stopping the other; but unanimously and with harmony agreeing, they all augment and contribute strength unto the intended work and operation: and therefore I call this *a semi-omnipotent engine*, and do intend that a model thereof be buried with me.

"99. How to make one pound weight to raise an hundred as high as one pound falleth, and yet the hundred pound descending doth what nothing less than one hundred pound can effect.

"100. Upon so potent a help as these two last-mentioned inventions, a waterwork is by many years' experience and labour so advantageously by me contrived, that a child's force bringeth up an hundred foot high an incredible quantity of water, even two foot diameter, so naturally, that the work will not be heard even into the next room; and with so great ease and geometrical symmetry, that though it work day and night from one end of the year to the other, it will not require forty shillings reparation to the whole engine, nor hinder ones day-work. And I may boldly call it *the most stupendious work* in the whole world; not onely with little charge to drein all sorts of mines, and furnish cities with water, though never so high seated, as well to keep them sweet, running through several streets, and so performing the work of scavingers, as well as furnishing the inhabitants with sufficient water for their private occasions, but likewise supplying rivers with sufficient to maintaine and make them portable from towne to towne, and for the bettering of lands all the way it runs; with many more advantageous, and yet greater effects of profit, admiration, and consequence. So that deservedly I deem this invention to crown my labours, to reward my expences, and make my thoughts acquiesce in way of further inventions."

In these extracts are contained the principal reasons for posterity supposing the Marquis to have been acquainted with the power of steam, and able to apply it to some useful purpose.

All of these articles, of which the 'Century' is made up, wanted only one condition to be complied with by their author, to satisfy the world that they were not mere idle dreams, or impudent boasts. But that condition is certainly an important one; viz. that he should have executed all, or at least some of the more important of the various machines which he thus describes. And on this point, in the case of the Marquis, there is unfortunately considerable room for doubt.

Still it is but just towards his memory to mention some circumstances, which, at least in so far as the "water-commanding engine" is concerned, seem to afford grounds for supposing that, whatever might be the true nature of the power by which it acted, or of the effects which it was able to produce, such an engine was actually constructed and was set to work.

On the 3rd of April, 1663,—the same year in which, as already stated, appeared the 'Century of Inventions,'—a Bill was brought into Parliament "to enable Edward Marquess of Worcester to receive the benefit and profit of a water-commanding engine by him invented; one-tenth part whereof is appropriated for the benefit of the King's Majesty, his heirs and successors," during a term of ninety-nine years; and this Bill was passed into an Act on the 12th of May following, not without formal, and apparently careful deliberation; though we still are uninformed as to how far evidence may have been called for, before either of the Committees, as to the reality and the specific particulars of the invention affirmed to have been made. Besides the passing of the Act, and the publication of the 'Century,' the principal circumstances that seem to show that the Marquis did more than merely imagine the construction of such an engine, are the following:—

(1.) It is expressly provided in the Act, "that a model thereof [*i. e.* of the engine] be delivered by the said Marquess or his assigns, to the Lord Treasurer or Commissioners for the

Treasury for the time being, at or before the nine-and-twentieth day of September, one thousand six hundred and sixty-three, and be by him or them put into the Exchequer and kept there." Unfortunately, we are not in a condition to prove that this model was ever so deposited. The Act was passed prior to the publication of the 'Century,' for in the Dedication prefixed to the latter, "To the Right Honourable the Lords Spiritual and Temporal, and to the Knights, Citizens, and Burgesses of the Honourable House of Commons, now assembled in Parliament," the Marquis speaks of "the Act of the Water-commanding Engine (which so chearfully you have past.") Yet in the whole course of the work he does not say either that the model had been deposited as directed, or that the engine was in course of construction on a great scale; although he does speak very confidently of the great feats he intended to perform, with the help of one "Caspar Kaltoff's hand," an "unparalleled workman both for trust and skill, who hath been these five-and-thirty years as in a school under me imployed, and still at my disposal, in a place by my great expences made fit for publick service;" expenses which he afterwards estimates at 10,000*l.* His expectations of realising a fortune by his engine were evidently exuberant; and with a heroic boldness not unworthy of the rest of his character and proceedings, he professes his design of first paying his debts, next of settling a competency to himself to live according to his birth and quality, and lastly, of dedicating the rest to the service of his king and country; who, however, fared little the better for that "bright reversion!"

(2.) In a letter to the Marchioness of Worcester from her confessor, dated 1670, which was three years after the death of her lord, the writer remonstrates with her ladyship for allowing her thoughts to be too much set "on the title of Plantagenet, and of disposing yourself for that greate dignity by getting of greate sums of money from the King to pay your deceased lord's debts, and enriching your selfe by the great machine and the like."

Along with this letter may be taken another still more curious document, preserved, like it, by the Beaufort family, and published in 1825 in Mr. Partington's edition of the 'Century of Inventions;' it is entitled, "*The Lord Marquesse of Worcester's ejaculatory and extemporary thanksgiving Prayer, when first with his corporal eyes he did see finished a perfect trial of his Water-commanding Engine, delightful and useful to whomsoever hath in recommendation either knowledge, profit, or pleasure.*"

(3.) In one or two copies of the first edition of the 'Century,' there occurs, as a sort of Appendix, a description of "a stupendious Water-commanding Engine," introduced by a preface, and concluding with a Latin eulogium and English panegyric, "composed, through duty and gratitude, by an ancient servant of his Lordship, (James Rollock,) who hath, for 40 years been an eye-witness of his great ingenuity, indefatigable pains, and vast expenses *in perfecting, for public service*, not only this most stupendious Water-commanding Engine, but likewise several other rare, useful, and never formerly heard of mathematical conclusions," &c., &c., the expressions in the third stanza of which are wonderfully descriptive of the powerful action of steam in raising water, as well as of its condensation when its work is done.

> "Here little *David* curbs the Gyant's brood,
> Small drops of Rain contend with *Noah's* flood;
> One weighs a thousand coming down apace,
> Weighs but himself when he hath run his race."

(4.) In the translation of the Travels in England of Cosmo de Medicis, Grand Duke of Tuscany, published in 1821, it is stated that "on the 28th May, 1699, his Highness saw at Vauxhall an hydraulic machine, invented by my Lord Somerset, Marquess of Worcester. It raises water more than forty geometrical feet, by the power of one man only; and in a very short space of time will draw up four vessels of water, through a tube or channel not more than a span in width."

So hard is it to discover, from such accounts, the true state of the case, that on the question of Lord Worcester's execution of any steam-engine, there has always prevailed great diversity of opinion. Nay, we even find one author of very considerable ingenuity, and of extensive though not always accurate research, in one of his works thinking it clear, for various reasons which he assigns, that this hydraulic machine must have been some species of steam-engine; and, probably, the identical "most stupendious Water-commanding Engine:"* while in another work, published not long before, he had said that the "'Century of Inventions' is called by Walpole, *with much truth*, an amazing piece of folly," and had unmercifully ridiculed "the overwhelming quackery of the Marquis of Worcester, and the absurd extravagance of his pretensions."†

We must not omit the tradition which attributes the origin of the steam-ideas of the Marquis to the period of his imprisonment in the Tower of London. His captivity there, which was of several years' duration, began in 1665, when he was arrested while on a mission from Charles II., who was residing at the Court of France. It is said that the Marquis, "in those deep solitudes and awful cells," one day observed the lid of the pot in which his dinner was cooking suddenly rise, forced up by the vapour of the water which the fire had heated; or, in other words, *by steam*. "Then it occurred to him that the same force which had lifted the lid might become, in certain circumstances, a useful and convenient moving power:" and hence—so runs the story—arose the 'Century of Inventions,' with its steam-engine all ready-made and acting;—at least in the mind of its contriver!

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* Historical and Descriptive Anecdotes of Steam-engines, by Robert Stuart. London, 1829, vol. i.

† Descriptive History of the Steam-engine, by Robert Stuart. London, 1824.

CHAPTER X.

COMPARATIVE CLAIMS OF SOLOMON DE CAUS AND THE MARQUIS OF WORCESTER—NATIONAL CONTROVERSY—LETTER FROM MARION DE L'ORME, PUBLISHED BY MISS COSTELLO—EXPOSURE OF A FRAUDULENT IMPOSTURE—PHILOSOPHICAL DISCOVERIES OF THE SEVENTEENTH CENTURY—GALILEO—TORRICELLI—PASCAL—OTTO DE GUERICKE.

THE comparative claims of Solomon De Caus and of the Marquis of Worcester have been a favourite subject of discussion with many writers in both France and England, the countrymen of the one and of the other respectively.

In the national competition as to those two ingenious projectors, De Caus had clearly the priority in point of time, by a whole half-century. But then he is not even alleged ever to have applied his hollow ball and tube, or,—to dignify them by a name which they could hardly claim,—his boiler and steam-pipe, to any purpose of utility; and in all probability he never either executed them on a great scale, or attempted to regulate the force which on a small scale he may have been able so to exert. The engine devised by Lord Worcester, on the other hand, if we are to believe the concurrent testimony of his own description and prayer,—of the correspondence between his widow and her confessor,—of the panegyric of his servant Rollock, and of the account given by Duke Cosmo de Medicis and his Secretary Magalotti,—would appear to have been at last executed on a scale large enough to produce very considerable hydraulic effects; and, although we must probably ever remain ignorant of the precise manner in which it acted, still there is no doubt that the language used by all parties in regard to it could best be explained by supposing that steam, in some one or more of its manifold ways of operation, was its moving power.

Considering the uselessness of the contrivance of De Caus, and the doubtfulness existing as to that of the Marquis, it is, indeed, only surprising that "the invention of the steam-engine" should have been attributed to either of them, with such confidence as both French and English writers have alternately shown.

In a work entitled 'A Summer amongst the Bocages and the Vines,' published in 1840, by Miss Louisa Stuart Costello, a lady favourably known to the world by several of her writings, appears the following letter, which she states, without hinting a suspicion of the truth of the statement, to have been written by Marion de l'Orme, in 1641, to M. de Cinq Mars.

"PARIS, Feb. 1641.

"MY DEAR EFFIAT,

"While you are forgetting me at Narbonne, and giving yourself up to the pleasures of the Court, and the delight of thwarting M. le Cardinal de Richelieu, I, according to your express desire, am doing the honours of Paris to your English lord, the Marquis of Worcester; and I carry him about, or, rather, he carries me, from curiosity to curiosity, choosing always the most grave and serious, speaking very little, listening with extreme attention, and fixing on those whom he interrogates two large blue eyes, which seem to pierce to the very centre of their thoughts. He is remarkable for never being satisfied with any explanations which are given him; and he never sees things in the light in which they are shown him: you may judge of this by a visit we made together to Bicêtre, where he imagined he had discovered a genius in a madman."

"If this madman had not been actually raving, I verily believe your Marquis would have entreated his liberty, and have carried him off to London, in order to hear his extravagances, from morning till night, at his ease. We were crossing the court of the mad-house, and I, more dead than alive with fright, kept close to my companion's side, when a frightful face appeared behind some immense bars, and a hoarse voice exclaimed, 'I am not mad! I am not mad! I have made a discovery which would enrich the country that adopted it.' 'What has he discovered?' I asked of our guide. 'Oh,' he answered, shrugging his shoulders, 'something trifling enough; you would never guess it; it is the use of the steam of boiling water.' I began to laugh. 'This man,' continued the keeper, 'is named Salomon de Caus; he came from Normandy, four years ago, to present to the King a statement of the wonderful effects that might be produced from his invention. To listen to him, you would imagine that with steam you could navigate ships, move carriages, in fact, there is no end to the miracles which, he insists upon it, could be performed. The Cardinal sent the madman away without listening to him. Salomon de Caus, far from being discouraged, followed the Cardinal wherever he went, with the most determined perseverance; who, tired of finding him for ever in his path, and annoyed to death with his folly, ordered him to be shut up in Bicêtre, where he has now been for three years and a half, and where, as you hear, he calls out to every visitor, that he is not mad, but that he has made a valuable discovery. He has even written a book on the subject, which I have here.'*

"Lord Worcester, who had listened to this account with much interest, after reflecting a time, asked for the book, of which, after having read several pages, he said, 'This man is not mad. In my country, instead of shutting him up, he would have been rewarded. Take me to him, for I should like to ask him some questions.' He was accordingly conducted to his cell, but after a time he came back sad and thoughtful. 'He is, indeed, mad now,' said he; 'misfortune and captivity have alienated his reason; but it is you who have to answer for his madness: when you cast him into that cell, you confined the greatest genius of the age.' After this, we went away, and, since that time, he has done nothing but talk of Salomon de Caus.

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* Here Miss Costello, in a note, adds the title of De Caus' book.

"Adieu, my dear friend and faithful Henry. Make haste and come back, and pray do not be so happy where you are as not to keep a little love for me.

"MARION DELORME."

To us, we confess, it always appeared that this letter smacked very strongly of having been concocted in the nineteenth century; and we now beg to inform those of our readers who might at first have been disposed to think differently, that it is, throughout, an attempt at an impudent and fraudulent imposture. So far from "your English lord, the Marquis of Worcester," having then been in Paris, there was not, and there never had been, at the date of the letter in question, either in France or in England, any such person as a Marquis of Worcester at all, nor was there any such title as that Marquisate in existence! Further, the first peer who bore that title was *not* the Marquis of Worcester of steam-engine fame; and the latter did not become either Earl or Marquis of Worcester for years after the date of the alleged interview with De Caus.

Henry, fifth Earl of Worcester, was not created a Marquis till 1642, when his son Edward, the author of the 'Century of Inventions,' was known as Lord Herbert. Edward, Lord Herbert, was created Earl of Glamorgan in 1645; and on the death of his father, the first Marquis, who died at the venerable age of eighty-five years, he succeeded to the Earldom and Marquisate of Worcester.

The few years before and after the middle of the seventeenth century form a most brilliant era in the history of discoveries in natural philosophy; and, quite independent of the hydraulic machine invented by the Marquis of Worcester, some great advances were made at that time, by philosophers whose names have not usually been associated with the steam-engine, towards the right explanation of principles upon which its action was at first to depend, as well as towards the construction of the apparatus.

Galileo, in 1640-41, surmised the true nature of a vacuum, and of the pressure of the atmosphere. His pupil Torricelli, pursuing the subject after the death of Galileo, invented the barometer, and proved the theory in 1643. Pascal, hearing of it, as he says, at Rouen, published, in 1647, his 'Nouvelles Expériences touchant le Vuide,' confirming the deductions of the Italian philosophers; and he caused to be made, in 1648, the memorable experiment of the Puy de Dôme, thereby establishing the variation in the pressure of the atmosphere at different heights, which Descartes had before conjectured.

Otto de Guericke had in the meantime applied himself to the same subject, and invented an air-pump, the effects of which he exhibited to the assembled German Princes at the Diet of Ratisbon in 1654. An account of this was published by Gaspar Schottus, first in his book 'De Arte Mechanicâ Hydraulicopneumaticâ,' in 1657, to which it forms an appendix; and afterwards, with several additions, as Guericke has informed us, in his 'Technica Curiosa,' Norimb. 1664, 4to. Robert Boyle passed some time at Florence in 1642, in which year Galileo died at a neighbouring village; he published, in 1660, 'New Experiments upon the Spring of Air,' and described therein an air-pump he had invented two or three years before, and which had been improved by Hooke. The experiments of the Accademia del Cimento, which are very full upon this subject, were published at Florence in 1666. Otto Guericke did not himself publish until a later period; for although he states in the preface to his work entitled 'Experimenta Nova Magdeburgica de Vacuo Spatio,' that it was completed on the 14th of March, 1663, yet he adds that, partly in consequence of illness, and partly from other occupations, a delay of seven years occurred in placing it before the world. It was at last published at Amsterdam in 1672, and its appearance then seems to have been in part owing to the exertions of certain illustrious friends of its author. Looking at chapters 27 and 28 of book II., and at the iconismi numbered XIV. and XV., where Guericke describes and delineates a cylinder with a *packed* piston and rod, and states his mode of forming a vacuum, by extracting the air under the piston by means of his air-pump, and thus producing a power for raising weights by the pressure of the atmosphere, we observe a great similarity to the apparatus in which Papin, several years later, when residing at Marburg, formed his vacuum by the condensation of steam.

The notion of the existence of such a thing as a vacuum,—which the old doctrine had taught that "Nature abhorred,"—and the right explanation of its true nature; the construction and use of the air-pump; the cylinder with its piston-rod, and piston packed so as to be air-tight although moveable in the cylinder, and with its upper surface exposed, so that the air should act on it as a power, when the close cylinder beneath was exhausted; are all so many distinct steps towards the formation of the atmospheric steam-engine of last century; which, under the hand of Watt, cast off altogether its dependence on the atmosphere, and for the first time became in every sense a true steam-engine; deriving its vacuum from the condensation of steam on one side of the piston, and its power from the impulse of steam on the other, and *vice versa*, according as the stroke made is downwards, and upwards, in uninterrupted succession.

CHAPTER XI.

DENYS PAPIN—HIS MEMOIR OF 1690—ATTEMPT TO FORM A VACUUM BY GUNPOWDER—HIS SUBSEQUENT ADOPTION OF SAVERY'S PRINCIPLE—HIS DIGESTER—MISTAKES OF ENGLISH AND OF FRENCH WRITERS IN REGARD TO HIS INVENTIONS—TRANSLATION OF HIS PAPER OF 1690.

WE come now to the Memoir in which Denys, or Dionysius Papin, in the year 1690, availing himself of the apparatus of Guericke, and of the true ideas as to a vacuum and the pressure of the atmosphere, of which we have just been speaking, set forth another important fact which he had observed. This was, that if a close cylinder were filled with steam, and the steam were then allowed to condense, a vacuum would be formed within the cylinder; and that, consequently, a moveable piston, fitted to the interior of the cylinder, would then fall, under the pressure of the atmosphere; just as it did in Otto Guericke's experiment, where the vacuum had been formed by the air-pump.

Papin mentions, in the outset of his Memoir, that he had applied steam to that purpose, in consequence of the failure of a previous attempt he had made to obtain a vacuum by the explosion of gunpowder, in the same cylinder, beneath the piston; the explosion always leaving the vacuum imperfect, on account, as he supposed, of a portion of the air which remained, or, as we should now say, of the gases which were the products of the combustion. But he proposed to carry out his ingenious idea of forming the vacuum by condensation, by the clumsy, tedious, and unprofitable expedient of removing the fire from beneath the cylinder, previous to each stroke or descent of the piston.

To practice, Papin seems never to have attempted to apply it, notwithstanding the suggestions to that effect contained in his Memoir; and we also find that on the appearance of a better invention for condensing the steam, eight years afterwards, Papin abandoned his own scheme, and betook himself to the construction of an engine, (which, however, turned out not to be a good one,) in which he made use of the new plan.

The best methods of applying the power to those various mechanical processes, which both Papin and his great advocate M. Arago have treated as difficulties of a very secondary kind, have in reality proved far otherwise; they have exercised the ingenuity of the most eminent engineers for upwards of a century and a half; and without their solution no mechanical power, however great, could be deemed of very much use to the world.

We reprint at full length a translation of the paper published by Papin in the "Acta Eruditorum Lipsiæ," for 1690, in which we have endeavoured to convey very literally the sense of the original; together with a fac-simile engraving on wood of the figure, with letters of reference, by which the paper in the Leipzig Transactions is accompanied. On this paper, Papin's claims to be considered one of the early inventors of the steam-engine, so eagerly urged by his countrymen, principally depend; and it is, at all events, an interesting record of very considerable ingenuity on his part.

"A NEW METHOD OF OBTAINING VERY GREAT MOVING POWERS AT SMALL COST. BY DENYS PAPYN.*

"IN the machine for a new use of gunpowder, which is described in the 'Acta Eruditorum' for the month of September, 1688, the first desideratum was, that the gunpowder fired in the bottom of the tube A A should fill the whole cavity with flame, so that the air might be entirely expelled from it, and the tube remain a perfect vacuum beneath the piston B B. But there it was mentioned that the desired effect could not be sufficiently attained ; but that, notwithstanding all the precautions there specified, there always remained in the tube about a fifth part of the air usually contained in it. Whence a two-fold inconvenience arises: viz. 1st, that in this way we lose half of the desired effect, so that scarcely can 150 lbs. weight be raised to the height of one foot, when otherwise 300 lbs. ought to have been raised, if the tube A A had been perfectly emptied; and 2ndly, that as the piston gradually descends, the force which makes it descend is itself diminished, as was also observed in the passage already referred to. Thus we have to provide, by some contrivance, that, as the moving force decreases, the resistance may in like manner decrease, so that it may be overcome by the aforesaid moving force until the end: just as in watches the unequal force of the main-spring, which moves the whole machine, is so regulated by art, that through the whole of its running down it overcomes the resistance of the wheels with equal ease. But it would be far more convenient if the moving force were to remain always the same, from the beginning to the end. Some attempts have, therefore, already been made to ascertain how a perfect vacuum could be obtained by the help of gunpowder; for in this way, were there no air to offer resistance beneath the piston, the whole column of the atmosphere pressing upon the said piston would press it with an equable force down to the bottom. But hitherto such attempts have been in vain, and always, after the flame of the gunpowder is extinguished, about a fifth part of the air remains in the tube A A.

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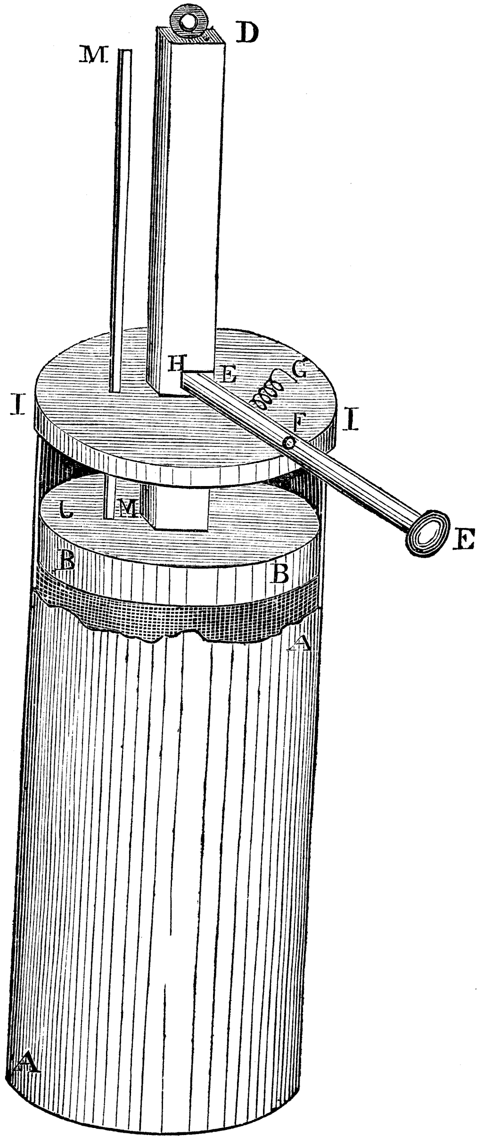
* Translated from the "Acta Eruditorum Lipsiæ" for 1690, pp. 410-414. The paper is also reprinted in the original Latin, in the "Origin and Progress of the Mechanical Inventions of James Watt," 1854, vol. iii. pp. 139-154.

"By another way, therefore, I endeavoured to attain the same end; and, since it is a property of water that a small quantity of it, converted into steam by the force of heat, has an elastic force like that of the air, but, when cold supervenes, is again resolved into water, so that no trace of the said elastic force remains; I felt confident that machines might be constructed, wherein water, by means of no very intense heat, and at small cost, might produce that perfect vacuum which had failed to be obtained by aid of gunpowder. But of the various constructions which can be contrived for this purpose, the following seemed to me to be the most suitable.

"A A is a tube of uniform diameter throughout, close shut at the bottom; B B is a piston fitted to the tube; D D a handle fixed to the piston; E E an iron rod moveable round an axis in F; G a spring, pressing the cross rod E E, so that the said rod must be forced into the groove H as soon as the piston with the handle has arrived at such a height as that the said groove H appears above the lid I I; L is a little hole in the piston, through which the air can escape from the bottom of the tube A A, when first the piston is forced into it. The use of this instrument is as follows:—A small quantity of water is poured into the tube A A, to the depth of 3 or 4 lines; then the piston is inserted, and forced down to the bottom, till a portion of the water previously poured in comes through the hole L; then the said hole is closed by the rod M M. Next the lid I I, pierced with the apertures requisite for that purpose, is put on, and a moderate fire being applied, the tube A A soon grows warm, (being made of thin metal,) and the water within it, being turned into steam, exerts a pressure so powerful as to overcome the weight of the atmosphere and force up the piston B B, till the groove H of the handle D D appears above the lid I I, and the rod E E is forced, with some noise, into the said groove by the spring G. Then forthwith the fire is to be removed, and the steam in the thin metal tube is soon resolved into water, and leaves the tube entirely void of air. Next, the rod E E being turned round so far as to come out of the groove H, and allow the handle D D to descend, the piston B B is forthwith pressed down by the whole weight of the atmosphere, and causes the intended movement; which is of an energy great in proportion to the size of the tube. Nor is it to be doubted that the whole weight of the atmosphere exerts its force in tubes so constructed; for I have established by experiment that a piston, raised to the top of the tube by the force of heat, shortly afterwards descends again to the bottom, and so on alternately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for a number of times, so that no suspicion can arise of air pressing beneath. Now my tube, the diameter of which does not exceed 2½ inches, yet raises sixty lbs. aloft with the same velocity as the piston is forced down into the tube, and the tube itself scarcely weighs five ounces.

"I therefore have little doubt but that tubes may be manufactured, the weight of each of which would scarcely amount to 40 lbs., and yet which could raise, at each operation, two thousand lbs. to a height of four feet. Moreover, I ascertained that one minute's time is sufficient for a moderate fire to drive the piston in my tube up to the top; but, as the fire ought to be proportionate to the size of the tubes, large tubes could be heated almost as soon as small ones: whence it is clear what vast moving powers may be obtained by help of this most simple contrivance, and at how small a cost. For it is known that the column of air pressing on a tube whose diameter is a foot, counterbalances nearly two thousand lbs.; but if the diameter be two feet, the weight would be nearly eight thousand lbs.; and that, in other dimensions, the pressure increases in like manner in the triplicate ratio of the diameters. Hence it follows, that the fire in a grate whose diameter scarcely exceeds two feet, might suffice to raise 8000 lbs. each minute to a height of 4 feet, if tubes were provided of such a height; for a fire might be made in a grate of thin iron, to be easily moved from one tube to another, and so the same fire might continually be preparing that most efficacious vacuum in one tube or another.

"If any one now will consider the magnitude of the forces to be obtained in this way, and the trifling expense at which a sufficient quantity of fuel can be procured, he will certainly admit that this my method is far preferable to the use of gunpowder above spoken of, especially as in this way a perfect vacuum is obtained, and so the inconveniences above recounted are avoided.

"In what manner that power can be applied to draw water or ore from mines, to discharge iron bullets to a great distance, to propel ships against the wind, and to a multitude of other similar purposes, it would be too long here to detail; but each individual, according to the particular occasion, must select the construction of machinery appropriate to his purpose. Here, however, I will in passing remark how greatly such a power is to be preferred to common rowers for moving vessels in the sea; for, 1st, the weight of the common rowers loads the vessel, and retards its progress; 2ndly, they require much room, and so are a great hindrance in the ship; 3dly, it is not always possible to find the requisite number of men; 4thly and lastly, the rowers, whether they are toiling on the deep, or resting in harbour, must always be supplied with needful food, whereby the expenses are greatly increased. But my tubes would, as has been already observed, have a very small weight to retard the ship; would also take up little room; might also be readily prepared in sufficient numbers, if once a manufactory were built and fitted up for that purpose; and, lastly, no fuel would be consumed for the said tubes, excepting at the time of the operation; while in harbour they would require no expenditure.

"But since common oars could not easily be moved by such tubes, paddle-wheels would have to be employed, such as I remember having seen in a machine constructed at London by command of the Most Serene Rupert Prince Palatine, which was put in motion by horses, by aid of oars of that sort, and which left a long way behind it the Royal barge manned by sixteen rowers. So, no doubt, oars fixed into an axis could be most conveniently driven round by my tubes, by having the rods of the pistons fitted with teeth, which would force round small wheels, toothed in like manner, fastened to the axis of the paddles. It would only be requisite that three or four tubes should be applied to the same axis, by which means its motion could be continued without interruption; for, while any one piston might be touching the bottom of its tube, so that it could drive the axis round no further, before being again propelled by the force of the steam to the top of the tube, the bolt of another piston could immediately be removed, the force of which in its descent would continue the motion of the axis; and so, again, yet another piston could be lowered, and exert its force on the same axis, while the pistons first pressed down were again being raised to the top by the force of heat, and so were gaining new force to move the said axis, in the manner above described. But one grate, containing a moderate fire, would be sufficient to raise all of those pistons in succession.

"Perhaps, however, some one may object that the teeth of the piston-rods, fitting into the teeth of the wheels, must in their ascent and descent communicate opposite movements to my axis; and that so the ascending pistons would hinder the movement of the descending ones, and the descending pistons would hinder that of the ascending ones. But this objection is a very trifling one; for machine-makers are well acquainted with a method whereby toothed wheels are so fixed to an axis that, when moved round in one direction, they carry the axis round with them, but when going round in the other direction they communicate no movement to the same axis, but allow it to be very freely turned round with an opposite movement. The principal difficulty, therefore, consists in finding the manufactory for easily making very large tubes, as I have more fully stated in the *Acta Eruditorum* for September, 1688. And for preparing that, this new machine ought to supply no small additional inducement; inasmuch as it very clearly shows that such very large tubes can be most advantageously employed for several important purposes."

CHAPTER XII.

THOMAS SAVERY—'THE MINER'S FRIEND'—DESCRIPTION OF HIS STEAM-ENGINE—USES TO WHICH IT COULD BE APPLIED—PAPIN'S INFERIOR IMITATION OF IT—ESTIMATE BY HORSE-POWER—SIR SAMUEL MORELAND—NEWCOMEN AND CAWLEY—THEIR GREAT IMPROVEMENTS—DESAGULIERS—AMONTONS AND DALESME—SMEATON.

IN the contrivance which has thus made the name of Papin, to say the least, quite as famous as it deserves, the vessel in which the steam was tediously generated, and then allowed slowly to condense, was at once boiler and cylinder; and, so long as it continued to fulfil alternately the functions of both of those vessels, it was necessarily unfit to do any really effective work. In order to the accomplishment of that desideratum, it was essential that the steam should, on the one hand, be steadily, continuously, and abundantly produced, and, on the other, that it should from time to time be condensed with at least tolerable rapidity. The honour of making this great step in advance,—the first that in fact led to the attainment of any really useful results from the employment of steam as a motive power of machinery, and which, therefore, it seems impossible too highly to commend,—belongs entirely to an Englishman, Captain Thomas Savery. Of his life and private history but little appears to be known.

But of his steam-engine Savery has luckily left us a very particular description, in a work entitled 'The Miner's Friend, or an Engine to raise Water by Fire described, and the Manner of fixing it in Mines, with an Account of the several other uses it is applicable unto; and an Answer to the objections made against it. By Tho. Savery, Gent. *Pigri est ingenii contentum esse his* *quae ab aliis inventa sunt. Seneca.* London, printed by S. Crouch at the corner of Pope's-head Alley in Cornhill. 1702.' The edition from which we copy this title is of that date; but Mr. Robert Stuart, at p. 34 of his 'History of the Steam-engine,' published in 1824, says, quoting from Robison, "The fact is, Savery obtained his patent in 1698, after hearing of objections; * * but, besides this, he had erected several of his engines *before* he obtained his patent;" "and," continues Mr. Stuart, "published an account of his engine in 1696, under the title of *The Miner's Friend*, and *a Dialogue* by way of answer to the objections which had been made against it, in 1699. What is most important is, that the letter-press of 'The Miner's Friend' is accompanied by a very clear and sufficiently well-executed engraving, including two figures, each of about twelve inches in height, of which the first represents "The Engine for raising Water by Fire," and the second represents the same engine "working in a mine." In the former, the various parts are all delineated on such a scale, that, with the aid of the particular description accompanying it, it is impossible to mistake either their proportion or their mode of action; and of both figures it may with perfect confidence be asserted that they are the first representations to be met with in the publications of any country, *of a real steam-engine doing useful work.*

Savery's engine, as so described and delineated, acted by two distinct principles; raising water, in the first place, by the pressure of the atmosphere forcing it into a vacuum formed by the *condensation of steam;* and, in the second, by *the expansive power of steam.* The steam from the *detached* boiler was let into a vessel called a receiver, and, having driven out the air, was condensed by the effusion of cold water, and a partial vacuum formed. A communication being then opened with a suction-pipe, twenty-four feet in height, the lower end of which was placed in a cistern or reservoir of water, that water was forced upwards, by the pressure of the atmosphere, into the receiver. When this was nearly filled, the communication with the suction-pipe was shut off, the steam was readmitted into the receiver, and by its expansive power forced the water contained in it up an ascending, or, as he called it, a force-pump. This second operation is similar to one of those experimentally tried by Porta, and indicated by Solomon de Caus; and not only indicated, but perhaps practised, by the Marquis of Worcester. The prior operation,—that of raising the water into a vacuum formed by the condensation of steam,—we believe to have been *original* with Savery. For, although both Portia and Papin had described the principle, they applied it in a different manner; and there is no proof, or even surmise, of its having been known to Savery when he invented his engine in 1696, or perhaps sooner. Indeed, Papin, with praiseworthy candour, as quoted by Belidor, ('Arch. Hyd.,' tome ii. p. 309,) writes, "What I say here is not to give room for believing, that Mr. Savery, who has since published this invention at London, is not actually the inventor. I do not doubt that the same thought may have occurred to him, as well as to others, without having learnt it elsewhere."

Switzer, in his 'System of Hydrostatics and Hydraulics,' published in 1729, says, p. 325, "Among the several engines which have been contrived for the raising of water for the supply of houses and gardens, none has been more justly surprising than that for the raising of water by fire, the particular contrivance and sole invention of a gentleman with whom I had the honour long since to be well acquainted; I mean the ingenious Captain Savery, some time since deceased, but then a most noted engineer, and one of the Commissioners of the sick and wounded.

"It was a considerable time before this curious person, who has been so great an honour to his country, could (as he himself tells us) bring this his design to perfection, on account of the awkwardness of the workmen who were necessarily to be employed in the affair; but at last he conquered all difficulties, and procured a recommendation of it from the Royal Society, in Trans. No. 252, and soon after a patent from the Crown, for the sole making this engine. And I have heard him say myself, that the very first time he played it, was in a potter's house at Lambeth, where, though it was a small engine, it forced its way through the roof."

Savery, in the second chapter of his 'Miner's Friend,' entitled "Of the uses that this Engine may be applied unto," enumerates—1. The working of mills, by raising water, afterwards to be employed in a steady stream turning water-wheels; 2. The supplying palaces, or noblemen's and gentlemen's houses, with cisternfulls of water, for domestic use throughout the house, for fountains, or in case of fire; 3. The serving cities and towns with water; 4. The draining of fens and marshes; 5. "I believe," he says, "it may be made very useful to ships; but I dare not meddle with that matter, and leave it to the judgment of those who are the best judges of maritain affairs;" 6. The draining of mines and coal-pits: all of which purposes may, he considers, be answered at far less cost by using his engine than by employing horse-power. And with regard to the last, he suggests that in very deep mines there might be a succession of steam-engines placed at various depths in galleries leading from the shafts.

We have already incidentally referred to Papin having, on the appearance of Savery's invention, abandoned his own idea of 1690, and proceeded to make a steam-engine on other principles, with several variations from that of Savery in the construction of the parts. Belidor, quoting from the work of Papin in 1707, says that "from the year 1698," (the date, it will be observed, at which Savery is said to have obtained his patent, and two years subsequent to the first publication of the description of his engine in the first edition of 'The Miner's Friend,' in 1696,) "he had made a number of experiments by desire of the Landgrave Charles of Hesse Cassel, to raise water by fire, which he had communicated to divers persons, and among others to Leibnitz, who answered that he also had entertained the same idea.

"This work having been interrupted," continues Papin, "would perhaps have been forgotten, had not Leibnitz, in a letter of 6th January, 1705, done me the honour to ask my opinion of the machine of Mr. Thomas Savery, of which he sent me the print made in London. Although its construction was a little different from ours, and I had not the description sent me, I saw at once that the English machine and that of Cassel were founded upon the same principle, as I showed to the Landgrave; which caused his Highness to resume the design of pushing on this invention, which, without doubt, is a very useful one, as will be seen hereafter. I can then testify that it has cost much time, labour, and expense, to bring it to its present state of perfection. It would be tedious to particularize all the unforeseen difficulties met with, and all the trials which have turned out contrary to expectation; and, therefore, I shall limit myself to making known how far what we now have is preferable to what we had done at first, and to what Mr. Savery has since done, that the public may not be under any mistake in the choice of these different machines, and may profit, without trouble, by what has proved so expensive; and likewise that they may see that their obligation to his Highness is not solely for having formed the first plan, but for having overcome the difficulties of the first execution, and brought matters to their present state of perfection."

Belidor, after this long quotation, goes on to observe—"M. Papin then gives the description of the machine he had executed, and forgets nothing to give it value. *But, whatever he may say, it is very far from being equally ingenious and complete with that of Mr. Savery*, which possesses the advantage of having within itself all the movements it requires, without any one touching it; whereas the other cannot act without the help of several men, one of whom at least is required to give his work uninterruptedly, with contrivances *which render this machine as imperfect as that of Mr. Savery is complete.* It does not, in fact, appear that the engine improved by Papin, after he was made acquainted with Savery's engine, was ever brought into practical use.

It deserves also to be mentioned that Savery, with the same attention to practical utility by which all of his mechanical proceedings seem to have been characterized, was the first to introduce the idea of horse or horse's power, as the measure of the force of an engine; a term which has since become so familiar as expressing a standard at once convenient in its use, and intelligible to every one. Sir Samuel Moreland had said, in 1683, in speaking of steam when "well governed according to the rules of statics, and by science reduced to measure, weight, and balance," that "then it bears its burden peaceably, (like good horses,) and thus would be extremely useful to the human race," &c. But that phrase can there be regarded only as a simile used in quite a general sense; while Savery goes on to show that an engine is capable of doing the work not only of as many horses as could at any one time produce an equal effect, but of as many as would have to be kept in order to produce the same effect constantly. "So that an engine," says he, "which will raise as much water as two horses, working together at one time in such a work, can do, and for which there must be constantly kept ten or twelve horses for doing the same, then I say, such an engine will do the work or labour of ten or twelve horses."* It is true that the modern use of the same standard has been limited to the lower of those two modes of comparison; but it may be doubted whether the other, employed by Savery, is not in truth the more exact one; as an engine can work day and night without requiring rest, while eight hours, or one-third of that period, are usually considered to be sufficient for a horse to work at one time.

Notwithstanding the importance which we now reasonably attach to the engine thus distinctly put forward by Savery, it met with but little acceptance from the miners to whom he addressed his description and his arguments in favour of its use. Arago says that there was but one exception to the general disregard of the benefits it promised to them; and, as during the term of his patent he does not appear to have made use of any safety-valve, there was evidently considerable danger, with the imperfect workmanship of those days, in using the highly heated steam which he is said to have ventured to employ.

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* 'Miner's Friend,' p. 29, 1702.

"I have known Captain Savery," says Desaguliers, "at York Buildings, make steam eight or ten times stronger than common air; and then its heat was so great that it would melt common soft solder; and its strength was so great as to blow open several of the joints of his machine: so that he was forced to be at the pains and charge to have all his joints soldered with spelter or hard solder.

"These discouragements," adds Desaguliers, "stopped the progress and improvement of this engine, till Mr. Newcomen, an ironmonger, and John Cawley, a glazier living at Dartmouth, brought it to the present form in which it is now used, and has been near these thirty years."[*] (The first edition of Desaguliers' first volume was published in 1734; the first edition of the second volume, from the third edition of which the above passage is taken, was published in 1744.)

Newcomen and Cawley became associated with Savery in the Patent obtained in 1705. The engine has, however, always borne the name of Newcomen.

The improvements introduced into it were very considerable, compared with the scheme of Papin, or the engine of Savery. In those first made, one cylinder was placed within another, and the interstice was filled with cold water, which effected the condensation with less trouble than the effusion of water, to which Savery had recourse; as he says, "the water, falling, causes by its coolness the steam, which had such great force just before, to [lose] its elastick power, to condence, and become a vacuum, or empty space."[*] The piston was tightened by packing with leather or rope, and by a stratum of water upon it. A separate boiler was used, as had been done by Savery, for the generation of the steam, and the consumption of water in it was supplied by a pipe from the top of the piston. A snifting-valve was applied for blowing out the air, and an eduction-pipe for getting rid of the water arising from condensation, with improved mechanism of cocks and valves. But the great invention for rendering the power applicable to practical purposes, consisted in a working lever, or great beam moving on a centre, one end being connected with the piston-rod, by means of an arch and chains, and the other with the pump to be worked by it, having a counterpoise for the piston. The subsequent introduction of the cold water into the inside of the cylinder, and the working of the cocks or valves from the great beam, were important points; and, by the last, the steam-engine was rendered a self-acting machine. The details underwent much improvement in the hands of Beighton, and, finally, of the great engineer Smeaton. See the particulars in Farey, ('Treatise on the Steam-Engine,' pp. 138-204.) The historical and mechanical information there given, and continued down to p. 308, will be found very deserving of an attentive perusal.

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[*] 'A Course of Experimental Philosophy,' vol. ii., p. 466, ed. 1763.

[†] 'The Miner's Friend,' p. 19.

It results from the facts we have adduced, that of the above machine, the first idea of the cylinder, packed piston and rod, and the use of the pressure of the atmosphere as a power, belong to Otto Guericke; the forming a vacuum by the condensation of steam in the cylinder to Papin, who probably was acquainted with the similar experimental process of Porta, conducted, however, with a cistern, instead of the more convenient cylinder; the separate boiler, and perhaps parts of the mechanism of the valves, &c., to Savery. But, whether the ironmonger and the glazier of Dartmouth were acquainted with what Otto and Papin had described in languages probably to them unknown, can only now be guessed at. That they knew something of what Savery had carried into practice six years before is likely, although Switzer appears to consider that they invented the whole. In the history of arts and sciences there have been many cases of apparent coincidence of inventions, of which, the theory of fluxions, bringing into opposition the great names of Newton and Leibnitz, forms the most illustrious instance.

"The way of leathering the piston," says Desaguliers, "was found by accident about 1713; having then screwed a large broad piece of leather to the piston, which turned up the sides of the cylinder two or three inches; in working, it wore through, and cut that piece from the other; which, falling flat on the piston, wrought with its edge to the cylinder, and, having been in a long time, was worn very narrow; which being taken out, they had the happy discovery whereby they found, that a bridle-rein, or even a soft thick piece of rope or match going round, would make the piston air and water-tight."*

Probably, also, the further packing of the piston by the ingenious method of a stratum of water resting on its plate, was discovered by accident. Its use led directly to a further invention of great importance, and even some elegance:—"One thing is very remarkable; as they at first were working, they were surprised to see the engine go several strokes, and very quick together, when after a search they found a hole in the piston, which let the cold water in to condense the steam in the inside of the cylinder, whereas before they had always done it on the outside."† And hence followed the substitution of the *rose-head*, to inject a shower of cold water through the interior of the cylinder before each descent of the piston, instead of the application of cold from without; in the first engine in which the injection was introduced into the cylinder, the water appears to have spurted straight up from the end of the injection-pipe. To obtain regularity of the injection, "they used to work with a buoy in the cylinder inclosed in a pipe, which buoy rose when the steam was strong, and opened the injection, and made a stroke; thereby they were capable of only giving six, eight or ten strokes in a minute, till a boy, Humphry Potter, who attended the engine, added (what he called *scoggan*) a catch that the beam always opened, and then it would go fifteen or sixteen strokes in a minute. But this being perplexed with catches and strings, Mr. Henry Beighton, in an engine he had built at Newcastle-on-Tyne in 1718, took them all away, the beam itself simply supplying all much better."*

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* Desaguliers, vol. ii. p. 533.

† Ibid.

Thus, then, by many successive stages had at last been formed a machine in which steam,—to use the figure of speech imputed to Sir Samuel Moreland,—had been reduced to weight, measure, and balance; but which could scarcely yet be said with truth to conduct itself very peaceably, or "like the best horses," under the various burthens it was intended to bear. For, although it certainly contrived to do a good deal of work, yet it did it in a fashion which was provokingly clumsy, imperfect, and irregular; it would not always move when ordered to do so, nor stop when its progress became dangerous; in the hands of those unaccustomed to attend, to clean, to water, and to exercise it, it would astonish the beholders by snorting wildly, rearing badly, and kicking viciously; it would break even its harness of chains, notwithstanding the "bridles" and "martingales" by which it was curbed; or again, when urged to go at a gallop and exhibit its best racing pace, it would sometimes take a fancy to spite its jockey, move even more sluggishly, work more feebly, and perhaps settle the unprofitable struggle by coming at last to a dead halt.

"It is now brought to very great perfection," writes Dr. Desaguliers, who would fain have had the credit of improving it beyond all the devices imagined by Lord Worcester, Savery, Newcomen, Cawley, and any others who might have had a hand in the Great Machine; "I shall show," quoth he, "that Captain Savery's method is not unuseful in many cases, especially when it is changed into the very simple engine that I have reduced it to, which I shall also describe." Yet this very perfect and simple engine was apt to have all the faults we have enumerated above: its original cost, also, was not small, and its appetite for fuel was voracious. This last might indeed be called its favourite weakness; for each time that the piston was raised, the cylinder had to be filled with steam, and was therefore heated to an equal degree; while, each time that the steam was condensed in order that the piston might fall, and a stroke be made, the cylinder was cooled down in proportion, and fresh heat, or in other words, more fuel, was wasted in recovering the steam-heat proper for the next rise of the piston.

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* Desaguliers, as above.

The names of Amontons and Dalesme, which have sometimes been included in the history of the steam-engine at the epoch of Savery and Papin, we need scarcely do more than barely mention. The "Fire-wheel" of the former, of date 1699, of which an elaborate description, with engravings, is given in the 'Mémoires de l'Académie des Sciences' for that year, and also in Leupold's 'Theatrum Machinarum,' 1724, (Tab. 53, fig. 2,) consists of a complicated apparatus, depending for its action more on the expansion of heated air than on steam. And of M. Dalesme's project, which bears the date of 1705, the only record that remains appears to be the following, contained in the 'Hist. de l'Académie des Sciences' for that year, and quoted by Prony, ('Arch. Hyd.,' ii. p. 90.) "M. Dalesme laid before the Society some ideas which it was thought might prove useful, and be deserving of the outlay requisite for experiments on a large scale. His notion is, that the force of the steam which rises from boiling water might be employed as a moving power: he has shown by a machine in which that force alone made water spout to a great height, how powerful it is." The effect described might evidently have been produced by something not more deserving the name of a machine than the hollow ball and tube of De Caus.

The improvements of Smeaton on Newcomen's, or the atmospheric engine, (as it was called from the pressure of the atmosphere on the piston being the moving power in the downward stroke,) are the last to which we are here called on to allude before entering on the consideration of those of Watt. In getting engines erected, Smeaton was so much baffled and annoyed by the irregularity and insufficiency of their work, arising often from the bad proportions of their parts, that he constructed a small experimental engine, not above four horses' power, from which he deduced a valuable table of the proportions of the parts and of their relative performance; the experiments are said to have been made about the year 1765, although Smeaton did not proceed to build large engines in accordance with the results obtained, till nine years afterwards; soon after which he designed several, some of them of more than a hundred horse power, and in which it was admitted that there was a considerable saving of fuel,—equal in some cases to one-third of the previous consumption. But those were not in existence at the period of Watt's life to which we must now attend; and even the table we have spoken of was not published by its author, but was found after his death among his papers, now in the possession of the Royal Society.

CHAPTER XIII.

DR. ROEBUCK—HIS HISTORY—CARRON IRON-WORKS—BORROWSTONESS—INTRODUCTION TO MR. WATT—PROGRESS OF THE NEW STEAM-ENGINE—TESTUDO BOILER—DIFFICULTIES WITH CYLINDER AND PISTON—PLATE-CONDENSER—CIRCULAR STEAM-ENGINE OR STEAM-WHEEL—DR. ROEBUCK'S EMBARRASSMENTS—MR. WATT'S LAND-SURVEYING AND CIVIL ENGINEERING—HIS VISIT TO SOHO—INTRODUCTION TO DR. SMALL—RENEWED EXPERIMENTS—PROPOSALS OF PARTNERSHIP WITH MR. BOULTON—PATENT OF 1769.

From the narratives of both Dr. Black and Dr. Robison, it is apparent that, next to the inventor himself, the person at first most deeply interested in the mechanical and commercial success of the invention, the origin of which has now been so fully detailed, was Dr. Roebuck; an ingenious and enterprising man, whose ultimate want of success in life ill rewarded his fondness for practical science, and his energetic exercise of very considerable talents and industry. It seems indeed a singular fatality, that even his early connection with the greatest invention of his age, full of future profit as it promised to be, and narrowly as we now see that it failed to realise that hope to him, was not only of no ultimate service to his own fortunes, but had nearly cut short the progress of the invention itself; which was long submerged, and well-nigh altogether lost, in the financial wreck in which his affairs became involved.

For the best account of the life and pursuits of the gentleman who was thus destined to become the temporary though unsuccessful associate of Mr. Watt in his important scheme, the public are indebted to the pen of the late Professor Jardine, of Glasgow College. From a biographical notice which he communicated to the Royal Society of Edinburgh, and which is published in their Transactions,* we find that Dr. Roebuck, who was born at Sheffield in 1718, and received some of his early education under the care of Doddridge and in companionship with Akenside, studied medicine at the University of Edinburgh, and formed there an intimate acquaintance with Hume, Robertson, and others of their eminent contemporaries. Graduating at Leyden, on his return to England he settled as a practising physician at Birmingham, where he rapidly rose into extensive and lucrative employment, and was at the same time enabled to gratify his inquiring habit of mind by numerous scientific researches, in which he engaged with ardour. The study of chemistry, one of his favourite pursuits, he now prosecuted practically, with great ingenuity and perseverance; inventing improved and economical processes for refining and working gold and silver, as well as for manufacturing many other substances commonly used in the arts; and, in conjunction with Mr. Samuel Garbett, establishing a large laboratory, where his various processes were profitably carried out on a very extensive scale. Sulphuric acid, which had previously been made, at great expense, in glass retorts, they succeeded, after many experiments, in preparing, by means of leaden vessels, at less than a fourth of its former cost; and on their establishing a manufactory of it at Preston Pans, in East Lothian, the consumption of the article increased enormously, and the profits of their undertaking became proportionally large.

Emboldened by this success, Dr. Roebuck proceeded to carry out a work of far greater extent and importance, which, both in a private and in a national point of view, has more than equalled the sanguine expectations then formed of its probable utility. Among the numerous objects to which he had turned his attention, was the smelting of iron-ore; a process which, as then commonly conducted, was capable, he had satisfied himself, of very great improvement. Having, with his partner Mr. Garbett, now

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Trans. R. S. E., iv. p. 65, 1796.

realised some fortune by the profits on his other processes, and being easily enabled, by the confidence reposed in his skill and judgment, to obtain the loan of the further capital that was necessary, he resolved to establish in Scotland a manufactory of iron on a great scale. To him was left not only the direction of all that concerned the buildings, machinery, and processes of the manufacture, but, in the first place, the selection of a proper site for the intended works; and on the banks of the river Carron, in Stirlingshire, he found united every natural facility for his purpose. In that situation, with great water-power, were combined the advantages of ready transport by sea, and supplies, in the immediate neighbourhood, of excellent iron-ore, limestone, and coal,—minerals which, after the lapse of a century, have in that district shown no signs of exhaustion.

The Carron iron-works, in their original state, were completed by the end of 1759, and the first furnace was blown on the 1st of January, 1760.

In planning the Carron machinery, Dr. Roebuck availed himself of the great talents of Mr. Smeaton, who has been justly termed the father of civil-engineering in Great Britain, and who, having in 1750 begun business in London as a philosophical-instrument-maker, was already fast rising to eminence in both of those professions. He had not, however, been previously brought into notice in Scotland; and the introduction of his skill into that country, in which he afterwards directed many important engineering operations, is one of the numerous proofs that Dr. Roebuck gave of possessing an observant and penetrating judgment. Among Mr. Smeaton's Reports, which were published by the Society of Civil Engineers,* and form an interesting memorial of his labours, are included several that were addressed to the Carron Company, concerning the supply and regulation of the water-power, the construction of blowing-machines on improved principles, of mills for boring the great guns known in the British Navy as *carronades*,* and other kindred matters.

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* In three volumes, quarto, 1812; which were followed, in 1814, by a fourth volume of his Miscellaneous Papers, comprising all of his communications to the Royal Society, printed in the Philosophical Transactions.

The works established under such advantageous circumstances, and directed by such able advice, did not fail to prosper; and they proved a lucrative investment of the means of their principal projector, as well as of his associated friends.

One of the great principles of the improved method of manufacturing iron, as practised at Carron, was the use of pitcoal instead of charcoal; which, although it had certainly been contemplated and even occasionally attempted in practice in England almost a century and a half earlier, it remained for Dr. Roebuck successfully to reduce to a general and useful system. An abundant and cheap supply of coal being thus an essential requisite for the continued prosperity of the iron-works, Dr. Roebuck was desirous of securing it by becoming the lessee of the extensive coal-mines belonging to the Duke of Hamilton, at Borrowstoness, where the coal workings were combined with salt-pits. The natural obstacles, however, which presented themselves, (arising chiefly from the great and unexpected depth of the workings,) were so formidable as at first greatly to hinder, and ultimately to render hopeless, the success of all his endeavours.

It was after he had engaged in that perilous adventure, but before its fatal issue was ascertained, that Dr. Roebuck was brought into connection with Mr. Watt. From the inventive genius of his new acquaintance, Dr. Roebuck was able to discern that great profit might accrue to the extensive establishments under his own care; his judgment, therefore, no less than his inclination, led him warmly to enter into schemes for rendering effectual in practice the principles which Watt communicated to him; and, an unreserved confidence having been established between them, in the correspondence which ensued are to be found the earliest contemporary records of the progress of the great discovery, which, as we have seen, had "flashed upon the mind" of Mr. Watt in the summer of 1765.

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* "In the early part of 1779," says Mr. James, in his well-known and admirable 'Naval Nistory,' "a piece óf carriage-ordnance, the invention, by all accounts, of the late scientific General Robert Melville, was cast, for the first time, at the iron-works of the Carron Company, situated on the banks of the river Carron, in Scotland. Although shorter than the navy 4-pounder, and lighter, by a trifle, than the navy 12-pounder, this gun equalled in its cylinder the 8-inch howitzer. Its destructive effects, when tried against timber, induced its ingenious inventor to give it the name of *smasher*." The new gun soon got the name of *carronade*, and those of the larger calibres were found to be so formidable from the force and weight of their shot, (from 32 to 68-pounders,) that within a very few years of the date of their invention they were introduced into almost every ship in the British navy; while a carronade of smaller calibre, (24 down to 12-pounders,) was in 1795 ordered to be supplied to the launch of every ship of the size of an 18-gun brig or above it, to aid in the service of cutting out vessels from the enemy's harbours.—See 'The Naval History of Great Britain,' by William James, vol. i. pp. 47 and 436, ed. 1826.

"I have tried my new engine with good success," writes Mr. Watt to Dr. Roebuck, 23 Aug. 1765, "for though I have not been able to get it perfectly air-tight from its bad materials, yet, immediately on turning the exhausting cock, the piston, when not loaded, ascended as quick as the blow of a hammer, and as quick when loaded with 18 lbs. (being 7 lbs. on the inch) as it would have done if it had had an injection as usual. The moment the steam-cock was opened, the piston descended with rapidity, snifting all the while, though the steam was very weak. On the faith of this I have set about a larger and more perfect model, having now little doubt of its performing to satisfaction." To Dr. Lind,*—"I have tried my small model of my perfect engine, which hitherto answers expectation, and gives great, I may say greatest, hopes of success (for certainty could not be called hope), in greater model now far advanced; in short, I expect almost totally to prevent waste of steam, and consequently bring the machine to its *ultimatum*."

On the 9th of September he informed Dr. Roebuck of various experiments and facts, from which he concludes, "That, in proportion as the sensible heat of steam increases, its latent diminishes, so, in the steam-engine, working with pressures above 15 lbs.

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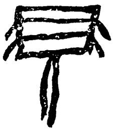
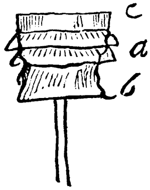
* 4 Sept. 1765.

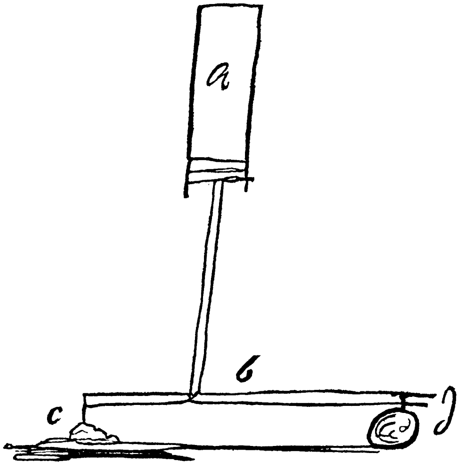
must be more advantageous than below it; for not only the latent heat is diminished, but the steam is considerably expanded by the sensible heat, which is easily added."

On receipt of this letter, Dr. Roebuck expressed his satisfaction at finding that Mr. Watt was so nearly ready to make his trial, and advised him to press it forward with all speed, whether he chose to pursue it as a philosopher, or as a man of business. After sending to the Doctor a calculation of an experiment on one of the old engines at Borrowstones, which, with a boiler 202 feet in area, a cylinder 32 inches in diameter, and of 5½ feet stroke, and 1454 cubic feet of steam produced per minute, made only 11½ strokes per minute, using at each stroke 1454 cubic feet of steam, Mr. Watt wrote on the 11th of October—"I have made a trial of my machine. It has not entirely answered my expectations, though it has no fault but what I think I can cure. The principal one, and I believe the only one, was the untightness of the piston, which I think I have found a remedy for. However, I am certain its consumption of steam will be extremely small, and the condensation quick enough; and it may possibly be some days before I can come to you, as I must remedy everything before I send it away." And again to Dr. Lind on the 12th of October,—"I have been making trial of my machine, but have not got the piston steam-tight yet; but hope I shall accomplish it. My error was applying the piston to it, it being more proper for purposes where the piston is drawn against the pressure than for engines where it flies from it. I now conceive this to be the best for it, as the cloth has a great latitude to adapt itself to a bad cylinder, and if the steam goes past one of the rings of cloth, the other will take it up. I am at present quite barren on every other article, my whole thoughts being bent on this machine; so I can write you nothing else."

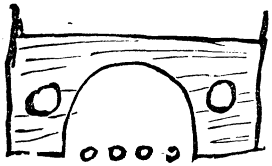


On the 16th of October, to Dr. Roebuck:—"On repeated trials of my machine I have had better success; it readily works with 10½ lbs. on the inch, and sometimes I made it lift 14 lbs. I still propose improvements on my piston, with which I am confident it will succeed to my utmost expectations. This is my present piston. At *a* are two collars of varnished cloth; *b* is the old part of the piston, which was made for Belidor's piston, and now remains naked. I propose adding another collar at *c*, and another somewhere on *b*, with which additions I hope it will be perfectly tight, as you will easily see that the addition of a collar increases the tightness vastly. As to the steam consumed, it is very little; my little boiler fills the cylinder in less than half a second after it has been exhausted. This is the way in which I tried it; *a* being the cylinder, *b* a lever fastened down by one end at *c; d* is a weight, which, by being moved backwards and forwards, determines the pressure. Now, in these circumstances, the weight being in a situation where the engine cannot lift it, and vacuum produced in *a*, it is plain, on opening the steam-cock, the steam will work into *a*, and fill it; to do which, as I said, it took less than half a second, which is known by its opening the snifting





valve so soon as it is *in equilibrio* with the air. So soon as the proposed alterations are made I shall forward it to you." And, on the 18th October: "Perfect or imperfect, I will send you the machine next week. I find nothing makes it work so well as a strong expanded steam." This was an "Inverted engine, with a new piston, the first not answering. The cylinder of this engine was five or six inches diameter, with a two-feet stroke; the inner cylinder was made of copper, not bored but hammered, and not very true. It was enclosed in a wooden steam-case, and placed inverted: the piston working through a hole in the bottom of the steam-case. This was the second of my new engines."



At the same time he describes the performance of a "Testudo" or tortoise-shaped boiler, "the grate formed of hollow tubes, filled with water, which evaporated 25 lbs. of water with about 4 lbs. of coals in about 44 minutes from the time of boiling; sometimes sooner, but with greater consumption of coals, those used having been very bad; and he speaks of his having another contrivance that would be be both less bulky, and more easy of execution.

On 10th November he sends detailed drawings and description for a covered cylinder and a piston, to be cast at the Carron works; whole inside length 7 feet, diameter 24 inches, to be made as truly round and equally wide as possible: which cylinder, however, although afterwards sent to Soho, was never used; having been very ill-bored, "though the best Carron could make at that time."

Before the end of the same year, he had discovered, as he thought, that he could make the piston "extremely air-tight, and at the same time have little friction," by means of English pasteboard, made of old ropes instead of paper, and oiled; and had also altered the plan of the condenser "from small pipes to thin interstices between plates: 16 double plates of a foot square, and half an inch asunder, will answer the purpose of 900 pipes of an eighth diameter. This has another advantage, viz. simplicity and greater ease in making. I have also thought on something new about the pump of the condenser, and also for the pump in the pit. Thinking on these things is a kind of relief amidst my vexations."

This "plate-condenser" also came to Soho, and many experiments were tried with it; but it came unsoldered, and the "drum condenser was substituted."

In March and April, 1766, the piston-rod and the new cylinder "for the large machine" were got ready, at Carron; and in the early part of that year occur the first intimations in Mr. Watt's correspondence of "a circular steam-engine" or steam-wheel, the idea of which had occurred to him, and which for a long time continued to divide his attention with the condensing engine. It was an alluring project, because, if successful, it would at once have provided a rotative motion for mill-work, a problem then unsolved by steam; but it took "a great deal more work" than its inventor had imagined; in May, 1766, it was "not yet quite finished, but near it," and so it remained for years, fresh difficulties arising in its execution as the old ones were overcome, till the patience of most men would have entirely given way.

At this stage of advancement it was,—when the great invention had been visibly and tangibly exemplified in a working model, and while its projector awaited, with eager hope, the performance, on a larger scale, of an engine, most of the parts of which were already constructed,—that the cloud of pecuniary difficulty which overhung the house of Kinneil increased so as grievously to darken all further prospects; discouraging, although not as yet entirely closing, that series of experimental trials which had hitherto been assiduously prosecuted. In September, 1766, Mr. Watt wrote to a friend: "I think I have laid up a stock of experience *that will soon pay me for the trouble it has cost me;*" yet it was between eight and nine years before that invaluable experience was made available so as either to benefit the public, or to repay the inventor; and a much longer period elapsed before it was possible for that repayment to be reckoned in the form of profit.

In the meantime, for some years longer, Roebuck was contending with his adverse fortune, and Watt incubating on such ideas, and, at intervals, practising such experiments, as occurred to him. Both seem,—though, as was natural, in different degrees,—to have continued to entertain tolerably sanguine hopes of the ultimate success of the new "fire-engine;" but neither of them could make any very decided step in advance, from the want, principally, of those easy circumstances, which, whether of time or of money, were now too commonly denied to both.

The necessities of an increasing family led Mr. Watt, in some measure, to forsake the occupation of a mathematical-instrument-maker, (from which, although the extent of his business had become considerable, the returns were not large,) for that of a land-surveyor and civil engineer,—a profession the higher departments of which were then little studied or practised in Scotland. Even in England the labours of Brindley and Smeaton had but recently announced the commmencement of a new era in that branch of applied science, while to the north of the Tweed they were only just beginning to be known and appreciated as they deserved. The building of the Eddystone Light-house, perhaps the greatest and most memorable of Smeaton's works, was completed in 1759: and we find that in 1760 he was employed by the magistrates and town-council of Dumfries to report on the best means of preserving and improving the navigation of the river Nith.* "In justice to Father Smeaton," wrote Mr. Watt,† after the lapse of half a century had raised up the gigantic works and established the fame of a Rennie and a Telford, "we should observe that he lived before Rennie, and before there was one-tenth of the artists there are now. *Suum cuique;* his example and precepts made us all engineers."

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* See his Reports, vol. i. p. 1.

† To Sir Joseph Banks, 18 Aug., 1812.

In 1767 Mr. Watt was employed, in conjunction with Mr. Robert Mackell, to make a survey for a small canal intended to unite the rivers Forth and Clyde, by a line known as the Loch Lomond passage; which, leaving the Forth some miles above Stirling, was proposed to pass by Bollat into the water of Endrick, and thence by Loch Lomond and the water of Leven, to Dumbarton on the Clyde. But, as it appeared from Mr. Smeaton's estimates and comparison of that line with another which was called the Carron passage, that the former would cost somewhat more, was more circuitous by nearly forty miles, and would have been attended with an additional loss of time in passing between thirty and forty locks, as well as by further expenses in keeping them in repair, the latter was preferred, and an Act obtained for the construction of that useful navigation. Mr. Watt having attended Parliament on the part of the subscribers to the Lomond scheme, appears from some of his letters to Mrs. Watt not to have been much enamoured of that public life of which he thus obtained a glimpse; when "close confined attending this confounded Committee of Parliament," he says, "I think I shall not long to have anything to do with the House of Commons again:—I never saw so many wrong-headed people on all sides gathered together. As Mac says, I believe *the Deevil* has possession of them."*

On his journey from London on that occasion, he appears to have made the acquaintance of Dr. Darwin, who writes to him from Lichfield, in August, 1767:—"Now, my dear new friend, I first hope you are well, and less hypochondriacal, and that Mrs. Watt and your child are well. The plan of your steam improvements I have religiously kept secret, but begin myself to see some difficulties in your execution which did not strike me when you were here. I have got another and another new hobby-horse since I saw you. I wish the Lord would send you to pass a week with me, and Mrs. Watt along with you;—a week, a month, a year! You promised to send me an instrument to draw landscapes with. If you ever move your place of residence for any long time from Glasgow, pray acquaint me. Adieu. Your friend, E. DARWIN." At the same time he first beheld a scene which was soon to become to him one of the most vital interest; for then it was that he first saw Mr. Boulton's great manufactory at Soho near Birmingham, to which he was introduced by Dr. William Small, who, along with Mr. Fothergill, a partner of Mr. Boulton, showed him the works. Mr. Boulton not being at home, those future friends and associates did not at that time meet; but to Mr. Watt's eye, well fitted to appreciate the union of science and art everywhere conspicuous in the various processes which he there witnessed, the manufactory appeared, and with truth, to be a perfect marvel of human ingenuity. "It was the first," says Arago, "which had been formed on such a large scale in England, and is still remarked for the elegance of its architecture. There, Boulton manufactured all sorts of admirable works in steel, plated goods, silver, and or-moulu; nay, even astronomical clocks, and paintings on glass. During the last twenty years of his life, Boulton devoted his attention to improvements in the coining of money. By uniting some processes originating in France, with new kinds of presses and an ingenious application of the steam-engine, he was enabled to attain at once an excessive rapidity of execution, and great perfection in the articles produced. It was Boulton who re-coined, for the English Government, the whole copper specie of the United Kingdom. The economy and excellence with which this great work was accomplished, rendered counterfeits nearly impossible. The executions," [for the crime of false coining,] "which in London and Birmingham were every year till then unhappily of frequent occurrence, altogether ceased. It was on this occasion that Dr. Darwin exclaimed, in the notes to his 'Botanic Garden,' 'If a civic crown was given in Rome for preserving the life of one citizen, Mr. Boulton should be covered with garlands of oak!'"

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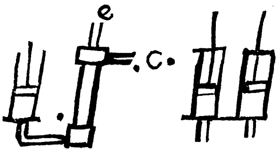
* To Mrs. Watt, London, 5 April, 1767.

Mr. Boulton, also, at a later date, planned and directed the arrangement of the machinery for the British mint on Tower-hill, and executed that for the coining department. He did the same for the great national mints of Petersburg and Copenhagen; as his son afterwards did for the still more extensive and splendid establishments of the East India Company, the Calcutta and Bombay mints. Mr. Boulton struck several fine medals at his mint at Soho, commemorative of persons and events in the late war with France; and, in particular, a beautiful one of Lord Nelson, on the occasion of the victory of Trafalgar, 21st October, 1805; the reverse representing the British fleet bearing down into action in two lines with the motto, "ENGLAND EXPECTS EVERY MAN WILL DO HIS DUTY." In a truly patriotic spirit, and with the consent and approbation of the Government, he presented one to each officer, sailor, and marine engaged in that memorable action.

Mr. Watt's inspection of the Soho manufactory, and the knowledge he acquired, through Dr. Small's friendly offices, of the talent, enterprise, and success with which that great concern was conducted, seem to have led him greatly to desire that his steam-engine could meet with so happy a fate as to be sheltered and cared for like the other machines which he there saw successfully at work. From the first letter that remains from Dr. Small to Mr. Watt, (of 7 January, 1768,) it is evident that some conversation had passed between them on the subject, and that Dr. S., while only informed of the ingenious discoveries recounted to him by Mr. Watt, and as yet ignorant of the precise nature of the connection between him and Roebuck, had formed a great esteem for his new acquaintance, had pressed him to settle at Birmingham, and had engaged, (which in any case he said they would most certainly do,) that Mr. Boulton and he should both assist him in every possible way. "I have no kind of doubt of your success," says Dr. S., "nor of your acquiring fortune, if you proceed upon a proper plan as to the manner of doing business, which if you do you will be sole possessor of the affair, even after your patent has expired. * * Whether it would be possible to manage the wheel and reciprocating engines by separate partnerships, without their interfering, I am not certain; if it is, Boulton and I would engage *with you* in either, *provided you will live here.* I am, in haste, dear Watt, your affectionate humble servant, W. Small."

They were evidently in greater doubt as to the expediency of forming any intimate business connection with Roebuck, some rumours of the dangerous extent of whose enterprises had probably reached Birmingham; although of him also, it is proper to add, Dr. Small writes, at the same date, "his integrity and generosity, everybody agrees, are great."

In the earlier part of 1768, Mr. Watt, "close-working," as he terms it, actively renewed his experimental alterations and trials of both the wheel or circulating engine, and the reciprocating or condensing one. Putty and other lutings, intended to keep the complicated valves of the former tight, in reality hindered them from shutting, by being metamorphosed into "the form of little balls;" and contributed to make the completion of that machine,—what it always remained,—a sort of labour of Sisyphus. But in the latter, great progress was made; for, although "the mercury" (with which the piston was packed) "by an unforeseen accident found its way into the cylinder, and played the devil with the solder," yet the piston was made to act by steam above it, as well as by the vacuum below it; the cylinder was set wholly in a steam-case; the piston was "extremely tight, and might easily be made tighter still; made of pasteboard, baked with linseed oil, and put on like the leather of a pump-box." He further proposed making two exhausting barrels instead of one, and giving them each half of its stroke, thereby producing a more perfect vacuum; "making the engine go of itself, that the strokes may be counted, and the water measured that is boiled away. These things are in hand, and will soon be done." This



was on the 29th of April, and by the 10th of May he had got the two new exhausting cylinders cast, bored, and partly turned, as well as new condensers made, and expected to have them going again by the end of the week.

"The two cylinders stand side by side; the pipes at bottom communicate with two condensers, which, by the pipe *c*, communicate with the large cylinder. There is a valve at *e* that prevents the air and water in the condenser from going into the big cylinder at the return of the piston of the exhauster, but obliges them to go out at the top of the condenser through the pipe *e*, having a valve at bottom to prevent their return. This pipe *e* has another use, viz., to measure accurately the quantity of water condensed [at] each stroke, by observing what space it occupies in this tube. I take this to be the best way of determining that article, if we can make the pistons of the exhausters tight, so that none may be introduced that way. As soon as I have got it completed I will write you, that I may either come to you and give you account of the success, or you come here and see the machine go. I am uneasy till I know the exact quantity of steam consumed; though from several circumstances I think it will answer hopes. At any rate the vacuum is good and sudden; the consumption undoubtedly the least possible."

After one or two trials which gave good promise, but left "several motions to adjust still," on the 24th of May he was at last able to send the following satisfactory report to Dr. Roebuck:—

"I received yours, and would have answered it sooner if I could have given you the satisfaction I now can. I this day had another trial of the engine with the double condenser: the vacuum was as before, 14 lbs. on the inch, and more readily formed, though this new apparatus is not perfectly air-tight. From some circumstances it was impossible to measure the water condensed in the way I proposed, but I found the engine could easily make twenty strokes per minute, and snift properly, when the steam was middling strong. I filled the boiler to a certain mark, allowed it to come a-boil, and boil one hour, in which time it wasted 300 cubic inches: I repeated this experiment with the same result nearly. Now 300, divided by 60, gives 5 inches in a minute, or $\frac{1}{4}$ inch each stroke. Now, the cylinder is $7\frac{1}{2}$ inch diameter, squared is 56; deduct $\frac{1}{4}$ to give square inches: 42 multiplied by 12, the stroke, 504 cubic inches—about $3\frac{1}{2}$-part of a cubic foot; but this used only the $\frac{1}{4}$ of an inch of steam. As we could not use all the steam, great part went off at the loading-valve, and some was needlessly expended from another cause, which I shall explain at meeting. Therefore I speak within bounds when I say that every cubic foot of the contents of the cylinder will require only one cubic inch of water to be evaporated. I am even of opinion that, in a large engine, with a strong boiler and a hot steam, the half of that quantity will be sufficient. I intend to have the pleasure of seeing you at Kinneil on Saturday or Friday. I sincerely wish you joy of this successful result, and hope it will make you some return for the obligations I ever will remain under to you."

This result, of which he was too good a mechanician not fully to comprehend the vast importance and great promise in every way, seems quite to have decided Mr. Watt on at all events immediately securing his invention by patent. From a friendly letter full of what was at least meant to be good advice,—a valuable commodity, of which, however, the supply too often exceeds the demand,—written by Professor Jardine to Mr. Watt in 1768, (probably early in the summer,) and dated from Kinneil, it is pretty apparent that the inventor had by that time become very doubtful of Dr. Roebuck's ability, under his evident embarrassments, to carry out the invention with the requisite vigour and resources. But, on the other hand, "the more," says Mr. Jardine, "Dr. Roebuck is convinced of the practicability of the scheme, the keener he is of carrying it [in] to practice yourselves for your mutual advantage;" and, while strongly urging him to keep up his spirits and hopes, and recommending him to devote some months to putting up a new engine at Bo'ness, with every aid that the Doctor could furnish, he adds, with characteristic discernment:—"You are surely very near to something that will be much to your advantage: the happiness, or, at least, the interest, of your family,—your own ease and amusement,—that life of ingenious indolence which you have often figured out to yourself, are all within prospect;—not to mention the honour of a discovery of so much importance, a circumstance which few would think so moderately of as yourself."

Mr. Watt being perfectly satisfied in his own mind of the value of his invention, went to London in August, 1768, to make arrangements for taking out a patent for it; only delaying the completion of that step till he should be able, if possible, to secure the aid of a fit associate in the execution of engines for sale, with an equitable adjustment of the chance of profit, or the risk of loss. Mr. Boulton had intended to have met him in town, but being detained at home, invited Mr. Watt to visit him at Soho,—at "l'Hôtel de l'Amitié sur Handsworth Heath," as he called his own hospitable house,—where he stayed for a fortnight, to the great joy of Dr. Small, Dr. Darwin, and Mr. Keir, who were asked to meet him. Keir, whom Mr. Watt calls "a mighty chemist, and a very agreeable man," was possessed of considerable literary as well as scientific attainments, and is still known as having been the author of a translation of Macquer's 'Chemistry,' and of an interesting paper on the crystallisation of glass; of another paper in the Philosophical Transactions on the congelation of the vitriolic acid; of a treatise on the different kinds of permanently elastic fluids or gases, in 1777 and 1779; of a fragment of a Dictionary of Chemistry in 1789–90; as well as of an Account of the Life and Writings of the eccentric Philanthropist, Thomas Day, in 1791.

On fully conversing with his guest as to the nature, position, and prospects of his invention, Mr. Boulton expressed a desire to be "concerned in the fire-engine;" but Mr. Watt, with that regard which throughout life he invariably showed not only to the rights and interests but also to the feelings of others, deferred entering into any agreement to that effect, until he should first have seen Dr. Roebuck again on the subject, and obtained his full concurrence. This he did on returning to Scotland in October, and the result was thus communicated by him to Mr. Boulton, dated the 20th of that month:—"When you were so kind as to express a desire to be concerned in my fire-engine, I was sorry I could not immediately make you an offer. The case is this:—By several unsuccessful projects and expensive experiments I had involved myself in a considerable debt before I had brought the theory of the fire-engine to its present state. About three years ago, a gentleman who was concerned with me died. As I had at that time conceived a very clear idea of my present improvements, and had even made some trial of them, though not so satisfactory as has been done since, Dr. Roebuck agreed to take my debts upon him, and to lay out whatever more money was necessary either for experiments or securing the invention; for which cause I made over to him two-thirds of the property of the invention. The debts and expenses are now about 1200*l.* I have been since that time employed in constructing several working fire-engines on the common principles, as well as in trying experiments to verify the theory. As the Doctor, from his engagements at Bo'ness, and other business, cannot pay much attention to the executive part of this, the greatest part of it must devolve on me, who am, from my natural inactivity and want of health and resolution, incapable of it. It gave me great joy when you seemed to think so favourably of our scheme as to wish to engage in it; I therefore made it my business, as soon as I got home, to wait on the Doctor and propose you as one I wished he would make an offer to, which he agreed to with a great deal of pleasure, and will write you in a few days, that if agreeable you may be a third part concerned, on paying the half of the cost and whatever you may think the risk he has run deserves, which last he leaves to yourself. If you should not choose to engage on these terms, we will make you an offer when the whole is more perfect, which I hope it will soon be."

* * * "If this reciprocating engine should not [answer,] it must be [from] some mechanical difficulty, which, I think, we may certainly get the better of. If Dr. Small should choose to be concerned with you in this, I have reason to think it would be agreeable to Dr. Roebuck, and would be highly so to me. If you should not choose to engage with this affair in its present state, or at any rate, you will let this letter remain a secret except to Dr. Small."

It was in the meantime determined, while awaiting Mr. Boulton's reply, that the patent should be taken out, so as at all events to secure the property in the new engine to its inventor, and those who might be associated with him in its manufacture. On the 5th of January, 1769, accordingly, the memorable patent for "A NEW METHOD OF LESSENING THE CONSUMPTION OF STEAM AND FUEL IN FIRE-ENGINES," was obtained; and the relative specification in due course, that is, within four months afterwards, enrolled. Dr. Roebuck had agreed, in consideration of receiving an assignation of two-thirds of the property of the invention, to defray the debt (of nearly 1000*l.*) incurred by Mr. Watt in making the previous experiments, and also the expense of the patent, and of any further experiments; while Mr. Watt was "to attend and conduct the experiments." In reality it turned out that Mr. Watt had to meet all the expenses with the exception of the debt of 1000*l.*, which Roebuck took, as agreed, upon himself; and although the funds thus required were not of any very large amount, they still were such as Mr. Watt might have had extreme difficulty in providing out of his small profits in the regular way of his business. We have ascertained that, at least to nearly the whole extent required for obtaining the patent, they were advanced by Dr. Black; who in this, as well as in many other ways, had both the ability and the inclination to promote the success of the labours of his young friend.

We need scarcely add that the sum thus provided was gratefully repaid, with interest, by Mr. Watt, when days of greater affluence had dawned upon him. But we feel pleasure in making known this instance, which we believe is not a solitary one, in which Dr. Black showed himself ready to aid a deserving neighbour less opulent than himself; as it has been alleged,—probably not altogether without reason,—that the learned Doctor was somewhat penuriously attached to the saving of money. The considerable fortune which he bequeathed to his relations, (upwards of 20,000*l.*,) certainly bore witness to his prudence as a financier no less than to his success as a physician; but on this subject we cannot do better than quote from one of his letters to Mr. Watt, written in the last year of his life,* in which he says, "You should study now to enjoy relaxation from business, and the amusements which are the most suited to your taste; but above all, relaxation and ease, and gentle exercise, and change of air. You need not be anxious now about your fortune. It is already abundant, and it will increase constantly, even while you are sleeping. It is, however, one of the follies of old age to be too intent on the accumulation of riches; and I feel in myself a degree of that inclination. Those of us especially who have made a little fortune by our own industry, set a high value on riches on account of the labour which they have cost us; and when time has put an end to other enjoyments, one of our greatest pleasures is to increase the hoard. We do not consider that it is already sufficient for every reasonable purpose. We have acquired a taste and a habit which we indulge. If you can be amused with the works of Horace, you will find in them many pleasant allusions to this folly, and ingenious expositions of the absurdity of it." We can hardly imagine either a more pleasant allusion to the foible in question, or a more sound exposition of the absurdity of it, than those thus delivered by the amiable and philosophic Doctor; whose discourse sounds partly as a warning against the sin, and partly as a rather complacent confession of its commission.

* Dr. Black to Mr. Watt, Edinburgh, 1 Feb., 1799.

CHAPTER XIV.

SPECIFICATION OF THE PATENT OF 1769—INTERRUPTED NEGOTIATIONS—CONTINUED EXPERIMENTS—EXPANSIVE POWER OF STEAM—SUCCESSFUL TRIAL OF ENGINE AT KINNEIL—PIPE-CONDENSER—FURTHER NEGOTIATIONS WITH SOHO—CONTINGENT AGREEMENT WITH DR. ROEBUCK—POSITION AND CIRCUMSTANCES OF MR. WATT.

WATT, while continuing his experiments at Glasgow, and his preparations for further trials of the engine "in the glen behind Kinneil," where "the burn afforded plenty of cold water" for condensation, and there was greater "freedom from speculation than about Bo'ness," now busied himself in making a draft of the Specification, which had to be given in and enrolled within four calendar months of the date of the Letters Patent. In the preparation of this document, which afterwards became one of great interest in the history of the steam-engine, not only from the nature of its contents, but also from the long and fiercely-contested litigation of which it was the turning point, he received the benefit of the advice of his friends Dr. Small and Mr. Boulton; and the event showed that their enlarged views of the principles on which it ought to be framed, were sound and judicious.

"Mr. Boulton and I," writes Dr. Small to Mr. Watt,* "have considered your paper, and think you should neither give drawings nor descriptions of any particular machinery, (if such omissions would be allowed at the office,) but specify in the clearest manner you can that you have discovered some principles, and thought of new applications of others, by means of both which, joined together, you intend to construct steam-engines of much greater powers, and applicable to a much greater number of useful purposes, than any which hitherto have been constructed; that to effect each particular purpose, you design to employ particular machinery, every species of which may be ranged in [one of] two classes: one class for producing reciprocal motions, and another for producing motions round axes.

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* 5 Feb. 1769.

"As to your principles, we think they should be enunciated (to use a hard word) as generally as possible, to secure you as effectually against piracy as the nature of your invention will allow. You might declare in some such manner as the following:

"First, you intend that the vessels in which powers of steam will be employed to work such engines as you may construct, shall be heated, before the working of the engines shall begin, at least as hot as the steam to be conveyed into the vessels, and that this heat of the vessels shall be rendered equable, whilst the engines work, by suffering them to be entered or touched in that time by no substance colder than the steam they are designed to receive, by covering them with materials which allow bodies so covered to cool very slowly, and by proper applications of heated bodies when they may be wanted. The vessels mentioned in this paragraph you call *steam-vessels.*

"Secondly, in the engines which you may erect to be worked, either wholly or partially, by condensation of steam, you intend that the steam shall be condensed in vessels distinct from the steam-vessels, though occasionally communicating with them. These vessels you call condensers; and, whilst the engine may be working, you intend to keep the condensers constantly at least as cold as the air then in the neighbourhood of the engines, by applications of water, and other means of cooling heated bodies.

"Thirdly, whatever air or other uncondensible elastic vapour may impede the operations of the engines, you intend shall be drawn out by machines in the manner of pumps, to be worked by the engines themselves.

"Fourthly, you intend that on different occasions the necessary steam shall be produced from different substances, solid or fluid, or partly solid and partly fluid, as may be most convenient; and also that the vessels in which the steam shall be produced, (which you call boilers,) shall be of different forms on these different occasions.

"Fifthly, in many cases you design to employ steam in producing reciprocal motions in a manner like to that in which portions of the atmosphere are now employed in ordinary reciprocating engines, to wit, by pressing at proper times upon pistons of proper structures.

"Sixthly, to produce, by means of steam motions round axes, you intend sometimes to employ reciprocatory joined to other machines, but more frequently steam-vessels of forms fitted to different purposes. These steam-vessels will be mounted on axes, and will contain weights, either solid or fluid, or partly solid and partly fluid; which weights, or the centres of their gravity, being constantly, whilst the engines work, pressed by steam beyond planes perpendicular to the horizon, and in which planes the axes will lie, will cause motions of the steam-vessels.

"Seventhly, in these last-mentioned engines, in which steam-vessels must move round axes, on some occasions you intend to use the condensers described above; but on others, to discharge the steam from the steam-vessels, through proper outlets, into the atmosphere.

"Lastly, to render pistons and other parts of the machinery air and steam-tight, instead of water you design to employ paper and pasteboard prepared with oils, oils themselves, or fat of animals, quicksilver, or melted metals."

Dr. Small adds, in a part of his letter written two days later, "I am certain that, from such a specification as I have written, any skilful mechanic may make your engines, although it wants correction; and you are certainly not obliged to teach every blockhead in the nation to construct masterly engines." The form of specification thus prudently recommended, differed but slightly from that ultimately adopted, which was signed and sealed on the 25th of April, and enrolled on the 29th of that month.

This letter was accompanied by one from Mr. Boulton,* in which he says that Dr. Roebuck had offered him "a share of his property in the engine, as far as respects the counties of Warwick, Stafford, and Derby," and then goes on: "I am obliged to you and him for thinking of me as a partner in any degree; but the plan proposed to me is so very different from that which I had conceived at the time I talked with you upon that subject, that I cannot think it a proper one for me to meddle with, as I do not intend turning engineer. I was excited by two motives to offer you my assistance—which were, love of you, and love of a money-getting, ingenious project. I presumed that your engine would require money, very accurate workmanship, and extensive correspondence, to make it turn out to the best advantage; and that the best means of keeping up the reputation, and doing the invention justice, would be to keep the executive part out of the hands of the multitude of empirical engineers, who, from ignorance, want of experience, and want of necessary convenience, would be very liable to produce bad and inaccurate workmanship; all which deficiencies would affect the reputation of the invention. To remedy which, and to produce the most profit, my idea was to settle a manufactory near to my own, by the side of our canal, where I would erect all the conveniences necessary for the completion of engines, and from which manufactory we would serve all the world with engines of all sizes. By these means and your assistance we could engage and instruct some excellent workmen, who (with more excellent tools than would be worth any man's while to procure for one single engine) could execute the invention 20 per cent. cheaper than it would be otherwise executed, and with as great a difference of accuracy as there is between the blacksmith and the mathematical-instrument-maker. It would not be worth my while to make for three counties only; but I find it very well worth my while to make for all the world.

"What led me to drop the hint I did to you was the possessing an idea that you wanted a midwife to ease you of your burthen, and to introduce your brat into the world, which I should not have thought of if I had known of your pre-engagement; but as I am determined never to embark in any trade that I have not the inspection of myself, and as my engagements here will not permit me to attend any business in Scotland, and as the Doctor's engagements in Scotland will not, I presume, permit his attendance here, and as I am almost saturated with undertakings, I think I must conclude to ——. No, you shall draw the conclusion; yet, nevertheless, let my conclusions be what they will, nothing will alter my inclinations for being concerned with you, or for rendering you all the service in my power; and although there seem to be some obstructions to our partnership in the engine trade, yet I live in hopes that you or I may hit upon some scheme or other that may associate us in this part of the world, which would render it still more agreeable to me than it is, by the acquisition of such a neighbour."

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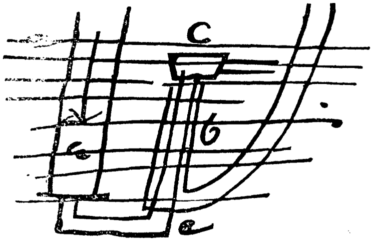
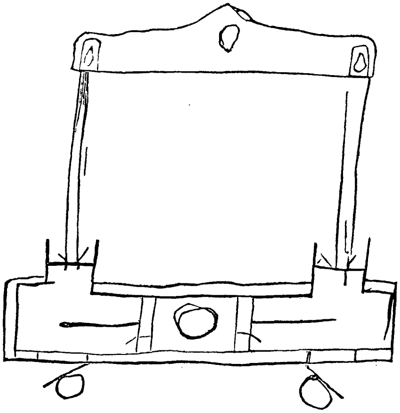
* 7 February, 1769.

Although the disappointing intelligence of the failure, so far, of the negotiation with Mr. Boulton, reached Mr. Watt just after he had written to Dr. Roebuck that from fresh trials of the engine, "its doing twice as well as the common [one] is, I think, absolutely certain, from what Mr. Jardine saw, and there is little reason to fear but what it will do all we expected," he did not allow it to interfere with the continuance of his experimental improvements. On the 22d of February he thus describes a further alteration of the condenser, with which he was much pleased:—"In the piston of the condenser there are valves as in a common pump; it is 2 inches diameter, stroke 6 inches; contains 18 cubic inches water. The pipe *b* of the condenser is surrounded with an outer pipe; cold water runs between. The pipe *b* and box



c contain above 9 cubic inches water; at *c* is a sliding valve which is opened, and kept open for a little space when the piston *a* is at the lowest. The mouth of the pump being above water, the piston, when it was at top, threw out almost all the water contained above it; when it is at the bottom, the water in the cistern runs in it at the valve *c* and fills the pump up to the level of the water in the cistern, and by that means puts out the water heated in the last stroke; when the piston is raised the valve is shut, and the steam, or what of it is not condensed, pushes the water before it into the pump, and endeavours to follow it into the pump, but is condensed with a crack. It is not possible, if the water be cold, that any of it can survive this operation; and the machine is simple and works easy. I propose working the condenser by a waterwheel." On the 14th of March he says:—"I this day made trial of the power of the engine, and found that, after it was clear of air, it readily lifted 620 lbs., and, I believe, would have lifted more, but had none at hand. The whole pressure on the piston is about 740 lbs.; this was with a steam not able to support above one, or at most two inches of mercury;" and, two days after, "Since I wrote you I added 80 lbs. to the load of the engine, making in all 704 lbs. net, which it lifted easily. However, the additional weight being a large mortar and inconvenient, I took it off and wrought it a few strokes with the 624 lbs., which it raises on half a revolution of the handle of the condenser, or the stroke of our pump. This seems to depend wholly on the coolness and quantity of water that passes through the condenser, which I have an easy method of increasing. I find this cylinder, being of cast-iron, and near one-eighth inch wider at one end than it is at the other, is not so steam-tight without oil as the block-tin one I had last was; I therefore make use of the oil-pump and train-oil, which answers perfectly well, keeping a constant circulation. The best and cheapest cylinders will be of block-tin; they will be defended from external injuries by the wooden case, and have nothing to fear from the inside."

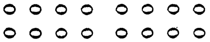
Not only was the "tolerably tight piston" here spoken of rather difficult to execute, but the condenser also was constantly undergoing further variations. Its pumps were made "frictionless," but then, they "afforded a lodgment for air;" that plan "was therefore rejected, and block-tin cylinders put in its place. These cylinders," he says, "are 3½-inch diameter; the piston moves up and down 1¼ inch; the piston-stalks are suspended on a beam on edges; the beam is made to vibrate by means of two spiral wheels that press down first one end and then the other. This spiral puts them down very quick in the first part of its motion, but during the last fourth of its revolution it only moves

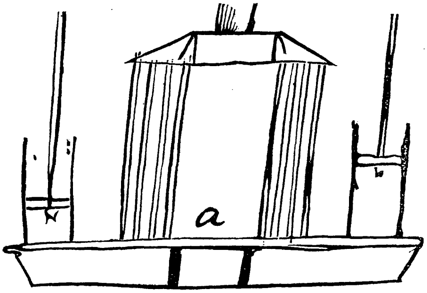


them 1¼ inch, that being the only time that anything beside friction opposes its motion, as it is then putting out its water and raising the whole power of the air on the other piston. During this part of the revolution, the valve at bottom is opened by a trigger, having little to oppose it, as that lobe of the condenser is then a plenum; then the water surrounding the condenser being higher by six inches than the top of the pumps, rushes up through the condenser and pump, and cools it. On trial, the condensation is more rapid than ever, the force necessary to move the condenser much less than you could well imagine, and the ease of execution quadruple what it ever was of any former condenser, for instance. This one is made of wood and block-tin."

Then comes a very early intimation of a most important principle, afterwards applied, with the best effect, in the manufacture of the improved engine, and included by Mr. Watt in his patent of 1782; viz., the use of the expansive force of steam as it rushes into a vacuum. Of this, it appears from one of his letters to Mr. Boulton, written in 1781, that he had thought in 1767; but he here most clearly sets it forth, as especially applicable to the wheel or circulating engines, which continued to divide his attention with reciprocating or condensing ones:—"I mentioned to your a method of still doubling the effect of the steam, and that tolerably easy, by using the power of steam rushing into a vacuum, at present lost. This would do a little more than double the effect, but it would too much enlarge the vessels to use it all; it is peculiarly applicable to wheel-engines, and may supply the want of a condenser where force of steam is only used; for, open one of the steam-valves, and admit steam until one-fourth of the distance between it and the next valve is filled with steam; shut the valve, the steam will continue to expand, and to press round the wheel with a diminishing power ending in one-fourth of its first exertion. The sum of this series you will find greater than one-half, though only one-fourth steam was used. The power will, indeed, be unequal, but this can be remedied by a fly, or several other ways."

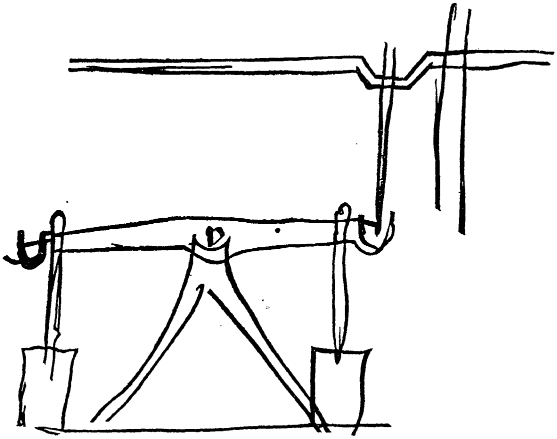
Gradually the completion of the engine "in great" at Kinneil approached: by 5th July, 1769, almost every part of it was ready for putting together; the boiler was set, the great beam hung; the condenser finished "much to his liking," with two pumps of tin, 9 inches in diameter, and the rest of it hardened lead, fastened to a strong frame of wood. The iron cylinder, (enclosed in another of wood,) the piston-rod, and piston, "the best Carron could produce," were yet "not over good," the cylinder being in one part oval, either from an inaccuracy of the mould in which it had been cast, of the action of the tool by which it had been bored, or from some injury received in setting it up;

and the adjusting and fitting together of all the parts occupied a long time. Yet at last, early in September, it was set to work; and, although the first trial did not appear to be decisive either way, chiefly owing to the inequality of the cylinder and consequent untightness of the piston, letting both the steam that drove it and the oil that "packed" it escape, yet Mr. Watt felt that he was still allowed "to flatter himself with hopes,"—too often now his only indulgence. "The boiler with a small fire," he says, "easily supplied more steam than we could destroy, although there were many outlets for it, which we took no care to stop, being employed otherwise. The boiler-top and wooden cylinder were very tight, as were all our vacuum joints and valves; the plates that let out steam were at the man-hole door and at the screws that fastened the steam-box to the wooden cylinder, which, had other things been right, we should soon have corrected. The only conclusion I can draw from this trial, is, that supposing we cannot employ oil to keep the piston tight, and that we cannot make it better than we had it, it would work easily with 8 lbs. on the inch, and would not consume above half the steam used by a common engine. Even this I will not positively affirm, although I think there is reason to believe it." To correct the elliptical error of the cylinder, he proposed hammering it from the outside on a truly cylindrical block of wood within, and making future cylinders of copper, for the convenience of such adjustments, instead of relying on the bad casting and boring of iron in those days; while soon afterwards he thus describes a new sort of condenser, which he called the pipe-condenser:—"The new condenser consists of two sets of pipes, eight in each set, thus:—  : they are each $\frac{3}{4}$ inch diameter and 18 inches long, 16 inches of which will be evacuated [at] each stroke of the pump; they are to be $\frac{1}{2}$ an inch distant from one another in all directions; each set is to be surrounded at $\frac{1}{2}$ an inch distant in a box of wood, through which cold water can be made to run at pleasure. They are joined at top by a thin cast-iron box, through which they communicate with the steam. It is made sloping at the ends, that as little useless water as possible may be in circulation. They are joined at bottom by another cast-iron box, through which they communicate with the pumps, which are of copper, 5 inches diameter; two diaphragms of wood prevent their communicating with one another, the box being continued only for strength. It was indeed originally made with an intention to have no communication at top, but the steam to enter at *a*, by which means the valves needed only be water-tight, whereas they must be air-tight above; but on condensation the steam, whenever it entered, (which would be as soon as any part of the pipes was empty,) would rise, or attempt to rise, through the water in the pipes, and would heat it; but the piston of the pump still ascending, that water would descend into the box below, and part might get into the pump, and be there converted into steam; not being exposed to much condensation at best, if it got no further than the box it would remain warm until the cold of the pipes made a vacuum, when it would boil and go to them to be condensed, and it is much to be feared that this heating and cooling might prolong the time of condensation. I have sometimes thought that something of this kind happened in the other condenser, and concurred with other devils to plague me; and indeed I was so out of humour with myself and it, I did not try all experiments I might have done to clear that up. I make use of the same beam and crank I had be-



fore, only I place these pumps at the extremities of the beam, where they have about four inches stroke. The way the crank is applied I think simple, yet answers as well as a crank can answer."

After the experiment at Kinneil had afresh inspired him with at least partial confidence, which, however, he always is careful to express with great modesty, Mr. Watt pressed Dr. Roebuck, who



was then about to set out on a journey into England, to try to conclude some bargain with Mr. Boulton; "which," he says, "even though it should appear a little hard for us, I would wish you to accept, from the following considerations:—1st. From Mr. Boulton's own character as an ingenious, honest, and rich man. You know him much better than I do, but the worst I have ever heard of him amounted to his being a projector. 2ndly. From the difficulty and expense there would be of procuring accurate and honest workmen, and providing them with proper utensils, and getting a proper overseer or overseers. If, to avoid this inconvenience, you were to contract for the work to be done by a master-workman, you must give up a great share of the profit. 3rdly. The success of the engine is yet far from being verified. If Mr. Boulton takes his chance of success from the account I shall write Dr. Small, and pays you any adequate share of the money laid out, it lessens your risk, and in a greater proportion than I think it will lessen your profits. 4thly. The assistance of Mr. Boulton's and Dr. Small's ingenuity (if the latter engage in it) in improving and perfecting the machine may be very considerable, and may enable us to get the better of difficulties that might otherwise damn it. Lastly. Consider my uncertain health, my irresolute and inactive disposition, my inability to bargain and struggle for my own with mankind; all which disqualify me for any great undertaking. On our side, consider the first outlay and interest; the patent; the present engine, about 200*l.* (though there would not be much loss in making it into a common engine); two years of my time, and the expense of models."

While thus, on the one part, it had come to be a question with the inventor, whether there would be "much loss" in converting the machine which was to revolutionize the whole face of the habitable globe, "into a common engine," on the other, both Mr. Boulton and Dr. Small had in the meantime engaged most of their money in other affairs:—"I am really sorry," quietly writes Mr. W. to the latter, "on my own account, that your engagements hinder you from entering into our scheme; for that ought to be the result of your deliberation. Though there are few things I have wished more for than being connected with you, on many accounts, yet I should be very loth to purchase that pleasure at expense of your quiet, which might be the case if you involved yourself in more business than you could easily manage, or, what is worse, find money for. Besides, this is not a trade, but a project. No man should risk more money on a project than he can afford to lose. I must, however, beg the favour of writing to you as though you were concerned."*

And Dr. Small, not outdone in either generosity or true friendliness, at once replies:†—"Nothing will give me more pleasure than to contribute in any degree to your prosperity, whether I can become an associate with you or not. Although I hate debts, yet on this occasion I have ventured to propose borrowing money from the only persons to whom I would be obliged in that manner. Should it suit them to accommodate me, I will accept Dr. R.'s offer immediately, as will our friend Boulton."

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* October 21, 1769.

† 5 November, 1769.

And again;—"I had your letter three days ago, and have held several conversations with our friend Dr. Roebuck about the scheme. He goes to London to-morrow, to stay one week, and in that time Boulton and I shall determine whether we can accept the offer he has been so obliging as to make us. Unluckily we have both just engaged in another scheme, which will very speedily require all the ready money we can at present spare, and I have a vast aversion to borrowing, although I would sooner borrow on this occasion than on any other I know, both because the engine must succeed, and because it is your affair. * * Your detail about the engine I have considered very carefully, and am in no degree discouraged. * * Boulton and I will do anything we can do to have you here, and to forward your success. Dr. R.'s proposal is perfectly agreeable to us; only as to me it is unfortunately made after the engagement of very near all my money. You shall hear from us again in less than a fortnight. In the meantime favour me with a few lines. All your friends here think of you with the highest esteem."*

The following was Dr. Roebuck's very moderate, and, indeed, liberal offer, referred to by Dr. Small; dated Birmingham, Nov. 28, 1769, and addressed "To Dr. Small and Mr. Boulton."

"Gentlemen,—Whereas Mr. James Watt has assigned to me two-thirds of the property of the patent of the steam-engine, which he took out some time in the course of the last winter, I hereby offer you one-half of the above two-thirds, or one-third of the whole patent, on condition that you pay to me such a sum, not less than one thousand pounds, as you, after the experiments of the engine shall be completed, shall think just and reasonable; and twelve months from this date you are to take your final resolution. I also oblige myself to procure Mr. Watt's assent to this agreement. I am, gentlemen, your obedient servant, John Roebuck."

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* 10 October, 1769.

It at once attained a ready assent:—"I have time only to say," writes Dr. Small to Mr. Watt, "that Mr. Boulton and I have agreed with Dr. Roebuck;"—whereupon Mr. Watt replies, "I received yours, and shake hands with you and Mr. Boulton on our new connection, which, I hope, will prove agreeable to us all."

The "final resolution" mentioned in Dr. Roebuck's proposal as to be taken at the expiration of one year, does not appear to have been then insisted on by any of the parties concerned in it; but soon after that time, great commercial embarrassment began to spread over Great Britain, and the poor Doctor's already wavering fortunes, unable to stand any fresh assault, fell in the general crash. This event might indeed have hastened rather than further retarded a definitive arrangement as to the steam-engine patent, and an attempt at its manufacture, but for the highly honourable and delicate feelings by which, it became very evident, all were alike influenced. "You are sensible," writes Dr. Small,* "that both Boulton and I engaged in the patent scheme much more from inclination to be in some degree useful to you than from any other principle, so that, if you are prosperous and happy, we do not care whether you find the scheme worth prosecuting or not." "I do fear," writes Mr. Watt,† "that in this affair I may have urged you too far and with too little delicacy; and that you have some reason from them to think more meanly of me than I deserve. I assure you, whatever I have said as to price, &c., I only meant in respect to my friend the Doctor, who I am of opinion ought not at present to risk anything of consequence, and has too much at stake in the matter. As to myself,

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[*] 17 September, 1770. [†] To Dr. Small, August, 1772.

I have never thought of receiving money for any part of my own property in it, and shall perhaps be willing to hold a much smaller share in it than you would ask me. Although I am out of pocket a much greater sum upon these experiments than my proportion of the property of the engine, I do not look upon that money as the price of my share, but as money spent upon my education. I thank God that I have now reason to believe that I can never, while I have health, be at any loss to pay what I owe, and to live at least in a decent manner. More I do not violently desire."

And again*—"I pursued my experiments till I found that the expense and loss of time lying wholly upon me, through the distress of Dr. Roebuck's situation, turned out to be a burthen greater than I could support; and not having conquered all the difficulties that lay in the way of the execution, I was obliged for a time to abandon the project. Since that time I have been able to extricate myself from some part of my private debts, but am by no means yet in a situation to be the principal in so considerable an undertaking. The Doctor's affairs being yet far from being reinstated give me little hope of help from that quarter; in the meantime, the time of the patent is running on. It is a matter of great vexation to me that the Doctor should be out so great a sum upon this affair, while he has otherwise such pressing occasion for the money. I find myself unable to give him such help as his situation requires; and what little I can do for him is purchased by denying myself the conveniences of life my station requires, or by remaining in debt where it galls me to the bone to owe.

"Notwithstanding my natural despondence, I am convinced that the machine may be made to answer in a very considerable degree, and in more forms than one, but that I am by no means a proper person to carry it into execution.

"The Doctor is on the contrary too sanguine, and always thinks things easier than they are. His present exigencies may also tempt him to insist upon higher terms for his property in it than it is really worth. But I expect, if you still think it worth while to engage in it, that you will both give him what you judge the value of it to you, and be at some pains to convince him of its being his interest to accept of it. I shall be content to hold a very small share in it, or none at all, provided I am to be freed from my pecuniary obligations to him, and have any kind of recompense for even a part of the anxiety and ruin it has involved me in."

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* To the same, 30 August, 1772.

* * "As to the engine, I am not afraid of being able to carry it on with a small capital, or almost none, provided the success was certain, or that I was in such circumstances as to be able to make the necessary experiments for establishing its merit. I have often mentioned to you that nothing gave me so much pain as the having involved Dr. Roebuck so deeply in that concern; and when I wrote you last, I would willingly have given up all prospect of profit to myself from it, provided he could have been indemnified. He is now willing to part either with the whole, or the greatest part of his property in it, upon such terms, as I dare say, in better times you and Mr. B. would have had no hesitation in accepting. Since Dr. R. saw you he is totally disappointed of the lease of the colliery at Wemyss, and was here lately in lower spirits than I ever saw him. His enterprising mind being by that means turned off from the coal schemes, his Bo-ness affairs going on badly, and he having no voice in the management of them, he had turned his thoughts toward the engine, and flattered himself he could finish the experiment on a small engine, not recollecting that I had been sufficiently successful with an engine of that size formerly, and that it was only in the 18-inch engine that the difficulties appeared. I have, however, dissuaded him from it, as without flattering myself, I cannot imagine that he can find out in a few days all the difficulties, and the means of avoiding them, which have cost me so much labour. I had also two other reasons against it, the exposing the contrivance to ignorant strangers, and that he could

not go on with it without directions, plans, and visits from me, which, in my present situation I cannot make.

"I talk of interesting you more in the success, because generosity *ought* to go a small way in directing our actions, and you have hitherto had little other motive excepting a promise of being concerned if we could agree upon terms. We may disagree about terms; we may from caprice or interest break that promise; or we may suddenly be called by death to another state, and our heirs may laugh at any promise that is not written upon stamped paper. Consider what I have said. Consider also that Dr. R. owes Mr. Boulton money, which will go in part of the price, which can never be so low as at present. I am sorry that there is occasion to ask a price, but it cannot be helped; the Doctor's circumstances oblige him to demand it if he parts with any great part of the property.

"I by no means intend to insinuate by this that I consider it necessary that you should pay down a sum of money before we would assign to you *any* part of the property; on the contrary, I think that you and Mr. B. ought to have a *certain* share without advancing to the Doctor or me, provided you took upon you the charge of the future experiments, and of finding money to carry on the business in case of success. What that share should be must be the result of some conversation between us. But I would much rather have the matter so settled that *at least* the half of the property should belong to Mr. B. and you. At any rate let us be on such a footing, that the experiments may go on, and the matter be concluded."*

There can be no doubt that even this contingent transfer of one-third of the property of the patent to his two friends was of some comfort to the now drooping spirits of the poor inventor; he much liked Boulton and Small, he valued their personal attachment, admired their mechanical ingenuity, and clear-sighted yet liberal business views and habits, and it was pleasant to him to be concerned with them even without much hope of immediately increasing his own fortune. Such hope, indeed, began to appear even more distant than ever; for it was now more than four years since "the capital improvement" had "flashed upon his mind, and filled it with rapture;" yet still, though fortified with a patent, and satisfied of the value of his invention, could it only be duly exemplified and carried out, he found himself left without any profitable return, and even involved in some debt. This was not yet, it is true, of any large amount, but still sufficient to begin to throw a lengthening shadow in the sunshine of his life; for "it cut him to the bone to owe." His family, also, had increased, and he had now attained to the onerous dignity of being the father of three children; but, unhappily, without receiving that triple proportion of corn, which, among the Romans, the "jus trium liberorum" brought with it. Those little voices, "whose crying was a cry for gold," were not to be stilled by the baser metal of a badly cast Carron cylinder, or the "block-tin and hammered lead" of a Glasgow condenser. So that we cannot wonder to find him writing, as he did some time before the acceptance of Roebuck's proposal,—"I am resolved, unless those things I have brought to some perfection, reward me for the time and money I have lost on them, if I can resist it, to invent no more. Indeed, I am not near so capable as I was once. I find that I am not the same person I was four years ago, when I invented the fire-engine, and foresaw, even before I made a model, almost every circumstance that has since occurred. I was at that time spurred on by the alluring hope of placing myself above want, without being obliged to have much dealing with mankind, to whom I have always been a dupe. The necessary experience in great was wanting; in acquiring it I have met with many disappointments. I must have sunk under the burthen of them if I had not been supported by the friendship of Dr. Roebuck. * * I have now brought the engine near a conclusion, yet I am not an idea nearer that rest I wish for than I was four years ago. However, I am resolved to do all I can to carry on this business, and if it does not thrive with me, I will lay aside the burthen I cannot carry."

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* To Dr. Small, 7 November, 1772.

And again, in March, 1770:—"It is a damned thing for a man to have his all hanging by a single string. If I had wherewithal to pay the loss, I don't think I should so much fear a failure, but I cannot bear the thought of other people becoming losers by my schemes, and I have the happy disposition of always painting the worst."

CHAPTER XV.

MR. WATT'S CIVIL-ENGINEERING—CONSTRUCTION OF THE MONKLAND CANAL—STEAM-BOATS FOR CANALS—SCREW-PROPELLER OR SPIRAL OAR, 1770—SURVEY FOR CANAL IN STRATHMORE—HAMILTON BRIDGE—CHANNEL OF THE CLYDE—CRINAN CANAL, AND OTHER WORKS—SURVEY FOR CALEDONIAN CANAL—TELFORD—RATE OF REMUNERATION OF ENGINEERS IN THE LAST CENTURY.

In this state of matters, every employment that enabled Mr. Watt to earn an independent income, and served to relieve his mind, now too constantly occupied with anxious and uncomfortable thoughts, was doubly welcome; and he was gradually led more frequently to forsake the solitary vigils of his workshop in the city, for the active labours of his profession of a civil engineer. "Somehow or other," as he modestly expresses it,—or, as we cannot doubt, from his ability and integrity having now become well known,—the magistrates of Glasgow had for two or three years past employed him in various engineering works of importance. In 1769 he made a survey and estimate for a navigable canal from the collieries at Monkland in Lanarkshire to the city of Glasgow, which was carried out under his own directions and superintendence, to the great advantage of the public as well as of the parties to the undertaking.

"I somehow or other," he says,* "got into the good graces of our present magistracy, who have employed me in engineering for them, (as Mr. Smeaton terms it); among other things I have projected a canal to bring coals to the town;—for though coal is everywhere hereabout in plenty, and the very town stands upon it, yet measures have been taken by industrious people to monopolize it and raise its price 50 per cent. within these ten years. Now this canal is nine miles long, goes to a country full of level free coals of good quality, in the hands of many proprietors, who sell them at present at 6*d.* per cart of 7 cwt. at the pit. There is a valley from Glasgow to the place, but it has a rise of 266 feet perpendicular above our river; I therefore set that aside, and have found among the hills a passage, whereby a canal may come within a mile of the town without locks, from whence the coals can be brought on a waggon-way. This canal will cost 10,000*l.* —is proposed 16 feet wide at the bottom, the boats 9 feet wide and 50 feet long, to draw 2½ feet of water."

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* To Dr. Small, 12 December, 1769.

"Vanity, also," he adds,* "bade me tell the Glasgow people they might be served as well at home as by strangers. The time has not been thrown away, for the *vaguing*† about the country, and bodily fatigue, have given me health and spirits beyond what I commonly enjoy at this dreary season, *though they would still thole amends.* Hire yourself to somebody for a ploughman; it will cure ennui."

And, although "a determination that everything should yield to the engine," led him to refuse going to London with the Bill for the Monkland Canal, yet, after the Act for it had been obtained, and he was again asked to superintend the execution of the canal, he felt himself obliged not to refuse that request. "I had now a choice," he says,‡ "whether to go on with the experiments on the engine, the event of which was uncertain, or to embrace an honourable and perhaps profitable employment, attended with less risk of want of success:—to carry into execution a canal projected by myself with much trouble, or to leave it to some other person that might not have entered into my views, and might have had an interest to expose my errors; (for everybody commits them in those cases.)

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* To the same, 3 January, 1770.

† " *Vagor* expeditus."—Hor.

‡ To Dr. Small, 9 September, 1770.

"Many people here had conceived a much higher idea of my abilities than they merit;—they had resolved to encourage a man that lived among them rather than a stranger. If I refused this offer I had little reason to expect such a concurrence of favourable circumstances soon. Besides, I have a wife and children, and saw myself growing gray without having any settled way of providing for them. There were also other circumstances that moved me not less powerfully to accept the offer; which I did; though at the same time I resolved not to drop the engine, but to prosecute it the first time I could spare.

"Nothing is more contrary to my disposition than bustling and bargaining with mankind:—yet that is the life I now constantly lead. Use and exertion render it rather more tolerable than it was at first, but it is still disagreeable. I am also in a constant fear that my want of experience may betray me into some scrape, or that I shall be imposed upon by the workmen, both which I take all the care my nature allows of to prevent. I have been tolerably lucky yet; I have cut some more than a mile of the canal, besides a most confounded gash in a hill, and made a bridge and some tunnels, for all which I think I am within the estimate, notwithstanding the soil has been of the very hardest, being a black or red clay engrained with stones. We are out altogether 450*l.*—of which about 50*l.* for utensils: our canal is four feet water and sixteen feet bottom. I have for managing the canal 200*l.* per annum; I bestow upon it generally about three or four days in the week, during which time I am commonly very busy, as I have above 150 men at work, and only one overseer under me, besides the undertakers, who are mere tyros, and require constant watching. The remainder of my time is taken up partly by headaches and other bad health, and partly by consultations on various subjects, of which I can have more than I am able to answer, and people pay me pretty well. In short, I want little but health and vigour to make money as fast as is fit.

"Now, Doctor, if you and your friend Hygeia can impart to me these blessings, I may be a rich and a happy man: otherwise, I can scarcely be either. I expect soon to have another touch at the engine."

In December, 1770, he writes: "Notwithstanding the desperate weather I am almost constantly at the canal. It costs me many a fit of chagrin; shows me many of my imperfections, &c.; but for all that, I find myself more strong, more resolute, less lazy, less confused than I was when I began it. However, I have no abatement of my headaches, in quantity or quality. I found the other day," he soon afterwards adds, "upon considering my circumstances, that, supposing the engine to stand good for itself, I am able to pay all my debts, and some little thing more; so that I hope in time to be on a par with the world. But I must say that my present life is a life of much vexation, besides bodily fatigue, of hunger, cold, wet feet, &c., which I could not endure had I the least of the gout, the gravel, or many other diseases. I don't know how it is, but I think my health rather better, in these gloomy months of December and November than it was in summer. I have a hundred men at work just now, finishing a great hill we have wrought at this twelvemonth. The nastiness of our clay grounds is at present inconceivable; the quantities of rain have been beyond measure.

"Our canal has not stopped, but is likely to do so, from our having expended the subscription of 10,000*l.* upon seven miles of the navigation, and having about two miles yet to make. We have, however, made a canal of four feet water for one of three feet subscribed to, and have also paid most abominably for our land.

"I decline only being the manager, and not being engineer. I wrote you before how grievous that first part of the business was to me, and it daily becomes more so. Everything has been turned over upon me, and the necessary clerks grudged to me; I am also indolent, and fearfully terrified to make bargains, and hate to settle accounts. Why, therefore, shall I continue a slave to a hateful employment, while I can otherwise, by surveys and consultations, make nearly as much money with half the labour, and, I really think, with double the credit? for a man is always disgraced by taking upon him an employment he is unfit for. I have no quality proper for this employment but honesty, which reproaches me for keeping it so long.

"Remember, in recommending me to business, that what I can promise to perform is, to make an accurate survey and a faithful report of anything in the engineer way; to direct the course of canals; to lay out the ground, and to measure the cube yards cut, or to be cut; to assist in bargaining for the price of work, to direct how it ought to be executed, and to give my opinion of the execution to the managers from time to time. But I can upon no account have anything to do with workmen, cash, or workmen's accounts, nor would I choose to be so bound up to one object that I could not occasionally serve such friends as might employ me for smaller matters. Remember also that I have no great experience and am not enterprising, seldom choosing to attempt things that are both great and new; I am not a man of regularity in business, and have bad health. Take care not to give anybody a better opinion of me than I deserve; it will hurt me in the end."*

"The cheapness of your canal," observes his able and zealous friend and correspondent, "astonishes me who have contributed to pay about 4500*l.* for each mile of another, which, locks excepted, had no difficulties to be compared with those you have surmounted. Among other instances of our wisdom, we have employed engineers, clerk, head-carpenters, &c., in such swarms, that their salaries have amounted to 1200*l.* per annum. And yet so invincible a propensity have mortal men to being duped, that the strongest and clearest remonstrances, and even want of money, could not enlighten us. But let that pass. I shall take care that the difference of your management shall be known."

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* To Dr. Small, 7 November, 1772.

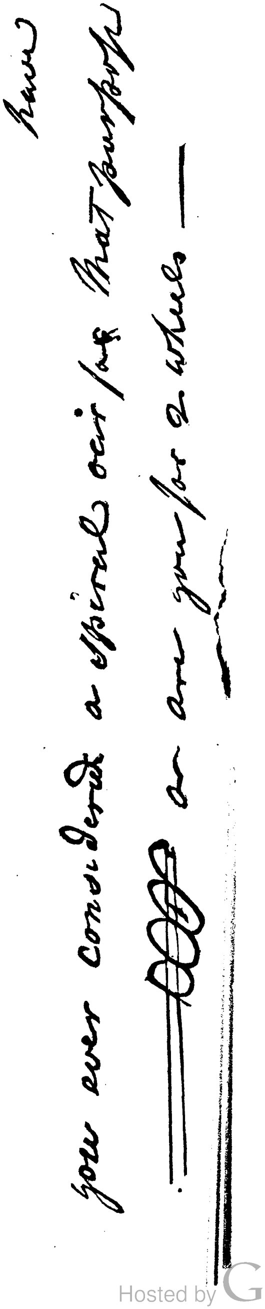
"You complain," he says a fortnight later, "I have not been sufficiently particular about our canal. As to the canal itself, it will, I hope, by Christmas be complete for seven miles, and of immediate and profitable use, because even from that termination we can afford to undersell others."

[Then follows a particular description, with measurements in cubic yards and superficial feet respectively, of the various cuttings, embankments, bridges, tunnels, and other works of the canal.]

"Our whole expense, act, surveys, &c., will be about 10,000*l.* spent. I have surveyed, levelled, planned, staked out, and measured the cube yards cut, of the whole, personally; I have also made bargains, superintended the work and accounts, and by myself and one clerk paid the cash. I have to the bargain been obliged to oversee every piece of work that was in the least out of the common road. I am now, in spite of a most [inclement] season, from five to six hours in the fields every day, and ride about ten miles. This is the one side. On the other, I am extremely indolent, cannot force workmen to do their duty, have been cheated by undertakers and clerks, and am unlucky enough to know it. The work done is slovenly, our workmen are bad, and I am not sufficiently strict. I am happy in the friendship of the principal residing proprietors, and am welcome to their houses as to my own, otherwise my wretched health could not have borne the fatigues I have undergone. What provokes me most is, that I am sensible that most people could in the same time have done much more and better work, possibly with as little trouble to themselves. I would rather face a loaded cannon than settle an account or make a bargain. In short I find myself out of my sphere when I have anything to do with mankind; it is enough for an engineer to force Nature, and to bear the vexation of her getting the better of him. Give me a survey to make, and I think you will have credit of me; I can draw tolerably; set me to contrive a machine, and I will exert myself; in whatever way you choose to employ me, I shall endeavour to follow your advice."

For two years and a half, from June, 1770, to December, 1772, Mr. Watt filled his office of engineer to the Monkland Canal, at his salary of 200*l.* per annum; which he considered a liberal allowance, and which he only resigned on the completion of that work, and his increasing engagements in other business of a similar kind. It was in the course of his correspondence in regard to these canals, that Dr. Small having mentioned the desire which Mr. Boulton and he entertained of moving canal-boats by the steam-engine, (which they at first proposed should be on the high-pressure principle):—"*Have you,*" says Mr. Watt in his reply, "*ever considered* A SPIRAL OAR *for that purpose, or are you for two wheels?*"* And to make his meaning quite plain, he accompanies his question by this rough sketch of A SCREW PROPELLER: even in the number of turns of the spiral not differing very greatly from such as in our own days, from a wide range of the most careful experiments, have been found to be best fitted for the purpose. The accompanying woodcut gives a faithful fac-simile of the remarkable passage in which this idea was started, and which so well deserves to be considered as adding another laurel to those which already adorn the name of Watt.

Unfortunately for the success of the project at that time, Dr. Small in his re-



Have
you ever considered a spiral oar for that purpose
or are you for 2 wheels —

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* To Dr. W. Small, 30th September, 1770.

ply observed,—"I have tried models of spiral oars, and have found them all inferior to oars of either of the other forms; I believe, because a cylinder of water immersed in water can be easily turned round its axis. This, I dare say, you perfectly know, so more need not be written. * * * * It is a great misfortune that spiral oars are but indifferent." Dr. S. appears to have understood the proposal as being for two oars, one on either side of the boat; whereas there can be little doubt that Mr. Watt, from using the singular, "a spiral oar," as opposed to *two* wheels, as well as from the very distinct explanatory sketch which he added with his pen, intended his propeller to work at the stern, as a boat is sculled by one oar. Thus, however, did it happen, that the project of the screw-propeller, to be worked by his own improved steam-engine, was propounded by James Watt *eighty-eight years ago;* that, when propounded, it was, by the discouragement of his friend, abandoned, or at least left *in retentis;* and that only his suggestion of it has remained, to be disentombed at this distance of time, as a fresh instance of his singular ingenuity and foresight, and as one of the greatest curiosities of what may already be termed the traditional history of engineering antiquity!

In 1770, also, he was employed by the Trustees for the Annexed Estates, (or the estates which in Scotland had been forfeited to the Crown by the attainder of their owners for participation in the rebellions of 1715 and 1745,) to make a survey for a canal from Perth to Cupar of Angus:—"I wrote you from Perth," he says to Dr. Roebuck,* "on Sunday last, since which time I have been close employed viewing this country and examining which would be the proper track for the canal, which I begin to survey to-morrow. You will, perhaps, think a week a long time to look about one; but it appears possible to make a canal from the hill of Kinnoul (opposite to Perth) to Forfar, which will measure above 36 miles, and that without a lock. There is a great deal of rough ground betwixt Perth and this place, but from hence to Forfar the ground is as well adapted as may be expected in any country. This valley of Strathmore is about 18 computed miles in length and six in breadth, but not a dead flat, as we imagined; the soil in general good, and of all kinds, from sand and gravel to clay, though I have seen none so strong as the Kerse clay, and very little of the country so flat. Agriculture is more advanced here than in some more southern parts of Scotland. There are some small proprietors of land, but it mostly belongs to great lords. There is here a great spirit of improvement, and great abundance of shell marl, but no fuel, except what is brought from Dundee over hills. * * I have had my health very well here, though much fatigued, and sometimes very cold with the piercing winds from the snowy Grampians that form the north side of this valley."

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* From Cupar of Angus, 15 April, 1770.

"My stay in Strathmore," he continues,* "was much longer than I expected. I had to examine and survey a country of 36 miles in length, and to hunt about for a course for a canal through country where Nature had almost done her utmost to prevent it; indifferent health, and weather viciously cold and stormy, were the attendants on my survey. The winds from the snowy Grampians, and snow even in the valleys a foot thick on the 10th of May, convinced me of the utility of what I was about;—for nothing can be more dismal than such weather in a country which nature and art have deprived of fuel."

And, thirty-six years later, in answer to the Earl of Breadalbane, who, as chairman of a Committee for making a navigable communication between the Tay and Loch Earn, had applied to Government for part of the balances remaining from the forfeited estates, on the ground that such a grant had been in contemplation by the board of Annexed Estates, and was prevented from being carried into effect only by the dissolution of the board on the restoration of those estates, he wrote,†—"I never made a

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* To Dr. Small, 9 September, 1770.

† 12 May, 1806.

survey from the Tay to Crieff and Loch Earn; but, at the desire of some gentlemen of that neighbourhood, I rode over the ground from the Linn of Campsie to Crieff, when I was making a survey from Perth to Forfar, (I think at the expense of the Trustees for Fisheries and Manufactures,) and found that a canal in that line was apparently very practicable; but it has occurred to me since, that the proper line of canal would be up the valley of Strathearn, from near the confluence of the Earn with the Tay; as it would by that means extend its influence over a greater tract of fertile country, and avoid the banks of the Tay, which, as far as I remember, are in many places very steep between Perth and the Linn of Campsie. But, as this view was taken so long ago as the year 1770, my memory upon the subject cannot be much depended upon."

In the same year, 1770, in which he made his survey in Strathmore, Mr. Watt made a survey, and drew out regulations for the contractor, for building a bridge over the Clyde at Hamilton:—"I have lately made a plan and estimate of a bridge over our river Clyde, eight miles above this; it is to be of five arches and 220 feet water-way, founded upon piles on a muddy bottom."* He also made a survey and report on the declivities and state of the bed of that river, by desire of the magistrates of Glasgow, who were then engaged in endeavours to improve its navigation and deepen its channel; endeavours which have ever since been strenuously sustained, and have met with well-deserved though then quite unexpected success.

The names of the other engineers with whose Reports on the same subject that of Watt has thus been associated, viz., Smeaton, Golborne, Rennie, Whidbey, Clark, Hartley, and Walker, bear conspicuous testimony to the advancement which Mr. Watt was now rapidly attaining in such pursuits, as well as to the clear-sighted discernment and public spirit of those who thus employed him.

In 1771 he gave in a Report on the best means of improving the harbour of Ayr, and made a survey for a canal of junction between the great (Forth and Clyde) canal and the harbour of Borrowstoness. In the same year he also surveyed lines for canals of junction between the Frith of Clyde and the Atlantic, at Crinan and at Tarbert, for the Commissioners for managing the Annexed Estates; his Report on those two lines being prepared and delivered in the following year. In 1773 he made a survey of a canal from Macrihanish Bay, on the Western coast of Argylshire, to Campbelltown, for the conveyance of coals; also of a canal from Hurlet to Paisley, and of the channel of the Water of Leven; as well as a survey, by desire of the Lords Commissioners of Police, for the purpose of rendering navigable the rivers Forth, Gudie, and Devon. To these were added a number of plans, mensurations, levellings, and estimates, at the request both of corporate bodies and of private individuals, which need not here be further particularized;—although among the number were some of very considerable local importance, such as plans for Port-Glasgow Docks and Harbours, 1769–1772; for supplying the town of Greenock with water, 1772–1773; &c., &c.

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* To Dr. Small, 21 December, 1779.

But the last and most remarkable of his civil-engineering works was that which he was called on, also in 1773, to perform for his employers the Commissioners of Police; viz., a survey and estimate for a navigable canal, to pass through the chain of rivers and lakes in the wild and remote tract of country between Fort William and Inverness; being the same line in which, at a considerably later period, the celebrated Caledonian Canal was successfully constructed by Mr. Telford. The first notice we find in his correspondence relative to that great work, is in a letter to him from Dr. Small, dated 1 May, 1773:—"Your very pleasing friend Mr. Hamilton was here on Thursday last, but could not stay. * * He told me you were to make a canal at Cantire. Of late a project has been talked of in England of making a passage for ships from Inverness to the Western Sea. It is said that it might be done easily, for that the ground between the two lakes, Ness and Oich, is level. Could you possibly survey this and judge of it, we could contrive to render the survey useful to you perhaps. Consider, and if possible do it before you come hither."

In answer to which, Mr. Watt writes:*—"In relation to your Inverness navigation, I know something about it. It would cost much money and time to make such a survey as I could set my hand to, and I am afraid the estimate would frighten you. The ground between Loch Oich and Loch Lochy is 50 feet high, and probably hard ground; the whole height, deducting the said 50, is 110 feet, the country hilly and rocky, few inhabitants, and labour very dear. I would like well to survey it, if paid for it; but I like better to come and visit you."

"The reasons," rejoins Dr. Small,† "for my pressing you to consider the project for joining the lakes were these:—It has been published by Pennant that an almost level course might be found for a canal. Your survey would be the first, and as things *now* stand, both you and it could be warmly commended to Lord Dartmouth, who is at the head of the Council of Trade, to Lord Sandwich, the First Lord of Admiralty, and to Lord North. Changes may in one year, you are very sensible, ruin these possibilities. The object is of great importance, and is tolerably well understood to be so, and may be further explained so as to be rendered popular. Advantages might arise from your having only proposed such a scheme to those great men, and having been shown to be most fit for executing it."

And, on the 17th of August in the same year, "I am appointed," writes Mr. Watt, "by the Court of Police to make a survey of the canal from Inverness to Fort William, and set out the week after next. I accepted of this merely in consequence of your desire, otherwise I should have delayed it till next season. I send you two covers; you forward your instructions and ideas of the utility in one of them, and your letter will probably reach me at Inverness, to which place it will be forwarded from Glasgow in case of my being gone."

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* 20 May, 1773.

† 2 June, 1773.

Dr Small's "ideas of the utility" of the projected canal were very clear and simple; and on the 29th of September he thus gives them, although prefacing the statement with an account of a long fit of weakness having greatly disabled him from writing: "When the herring-fishery was attempted by the people on the eastern coast, they found their own sea furnished neither plenty of the fish, nor fat ones; therefore they tried to send vessels to the Western Sea. At the best season, these ships could seldom get round by the Orkneys, on account of periodical westerly winds and currents; and the voyage through the two channels is long and dangerous. Had the canal then existed, I believe the fishery would by this time have been established; and for want of it, besides the disappointment in that contingency, a vast number of the fishing people that used to swarm upon the eastern coast have left the kingdom, the people having changed their diet, and now using less fish. Besides, it was necessary, on account of the nature of the voyage, to use too large and expensive vessels.

"Next, could a canal be made to admit armed vessels, no enemy could ever venture into the Irish Channel, or near the Western Isles.

"The returning voyage, even to London from America, would he shortened one-third upon an average, by steering round the North of Ireland for this canal, on account of the wind in those latitudes. The banks of the canal would prove a seminary of herring-fishers, whale-fishers, and Newfoundland-fishers, for canals tend more to breed watermen than even sea-towns.

"More artisans living on the eastern coast of Scotland than on the western, and they daily growing more expert, they would have more easy access to the American market, the only one that is likely to be long supplied with manufactures from Britain, &c., &c., besides all the inland advantages."

Before his survey was completed, Mr. Watt was suddenly recalled to Glasgow by a grievous domestic calamity, of which we shall hereafter more particularly speak; but he then wrote to Small:—"As far as I saw of the canal, it is practicable. Loch

Oich is 100 feet above the sea, and the summit of Lagan na Drum, that separates from Loch Lochie, only 20 feet above Oich, and all good gravel. There is plenty of water, and Oich 4 miles long for a reservoir. I left Morison, my surveyor, who is tolerably accurate, to complete the survey. I had a miserable journey home, through the wildest country I ever saw, and the worst conducted roads: an incessant rain kept me for three days as wet as water could make me. I could hardly preserve my journal-book."

"Pray does the country you have surveyed," replies the Doctor, "furnish timber fit for ship-building, or wood for charcoal, or mines of any valuable kind? I had no suspicion that Loch Oich was so far above the sea, and therefore had hopes that ships might be built in it, and their cannon, ballast, &c., might be cast on its banks, and their bolts, &c., be made there. Could many small canals be cut from the lakes and the great canal, on both sides; I mean such as could carry boats from one to three tons burden? You say the road from the fort is badly planned. Pray mention this to the Commissioners of Police, who I understand are your present employers. It may produce both an improvement and employment for you for years." "I do not wonder the people migrate from the country you have described, to America, or anywhither. Pray have not all these mountains formerly been forests, and why does not timber now grow upon them, as they are not cultivated? Nothing but *incessant* cultivation can hinder any spot in America, from latitude 50° southwards, from producing trees. I am led by this and many other reasons to suppose, nay, to believe, that the frozen space of the globe is annually increased, at the rate of about the 300th part of a degree of latitude at a medium, or more; so that after a certain number of years all Europe, and finally the whole surface of this earth, will be frozen, as the moon is now and has long been. *Violà une théorie;* one good property of which is, that I shall not live to suffer the disgrace of seeing it refuted by experience. And then it ought exceedingly to forward the execution of my project for producing perpetual summer; of which I will be bold to say, that if all the gunpowder which has been spent by their Imperial and Royal Majesties, the Emperors and Empresses of Constantinople, Germany, and Russia, the Kings of France, Spain, Britain, and Prussia, within these last twenty years, had been laid out upon it, the powder would have produced at least as much benefit to everyone of them as it has done by being expended on their own schemes. I have had thoughts of writing a circular letter to these potentates, and if you give me any encouragement, notwithstanding my laziness, I will still do it, although there is but little to be made of kingly heads, I fear."*

"As you are a great advocate for the Inverness Canal, and main adviser for my undertaking the survey," again writes Mr. Watt, "now I find myself in a kind of scrape, I must call upon you to help me out. The case stands thus:—Freight from Forth to Clyde and back, 20*s.* per ton; time of passage from 10 to 40 days; ordinary passage 20 days. Distance by outside Orkneys 635 geographical miles; by Pentland 575. From Buchan-ness to Mull by Orkneys 375; by Pentland 315. By the canal, distance by sea, Buchan-ness to Inverness 105; artificial navigation 23 English miles; Freshwater loughs 30¼ geographical ditto; Fort William to Mull 30 ditto. Average rate of vessels sailing, founded upon a twenty days' passage, 30 miles per diem. Passage, Buchan-ness to Mull by Orkneys, 12½ days; by Pentland, 10½. Time of passage by canal, the sea part 135 miles, 4½ days; the loughs one day: the four canals, 23 miles, two days: total by canal, Buchan-ness to Mull, 7½ days. Saving over Orkney passage five days; over Pentland passage three days. Summer insurance round Orkney 30*s.* per cent.; winter ditto about 3*l.*; but no wise under-writer will put his name to such a policy. Winter insurance from Clyde to Fort William 25*s.* per cent.; from Murray Firth to Leith 20*s.* The expense of making a canal for 10 feet water will be about 160,000*l.*, besides land. *Violà*

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* 27 October, 1773.

les faits. I want your opinion of the proper method of proving the advantages and valuing them in money, so that it may appear what toll can be afforded, and whether it will compensate the expense. Be as full as you please; for unless some strong arguments appear, I am afraid, as a just judge, I must myself pass sentence of condemnation, or leave the poor canal to the mercy of the public.

" Give me your opinion of the best manner of digesting a report of this matter, and of the size of the plan. I think of doing it in one long plan, upon a scale of an inch to the mile; it will be five feet long, and may be printed in three pieces, if it merits that expense. A lesser scale would not show the parts, and a larger would not show the connection.

"Since my last I have been close writing upon this subject."

" I have now finished," he adds,* " my reports and plans of the Inverness Canal, and have sent a copy of them to Lord C[athcart], who would not fail to show them about. The principal copy of the report I only finished this week; that I sent to Lord C. was only an outline."

The great engineer, Mr. Telford, throughout the whole of his lengthened labours in connection with so vast an undertaking, has borne testimony to the particular correctness and value of Mr. Watt's survey; a circumstance which will be our sufficient excuse if for a moment we anticipate the course of our narrative, to explain the gratifying circumstances in which Mr. Watt at length witnessed the completion, on an enlarged and magnificent scale, of that great national work, on behalf of which his early skill and energy had thus been enlisted. He had also in the meantime† been consulted, as to the same line, by Mr. Rennie; whose scheme, however, was not then carried out.

On Telford's return from Scotland towards the end of the year 1801, he wrote to Mr. Watt, informing him that he had been engaged there since the month of July, employed in making surveys by order of the Treasury Board, one of the objects prescribed to him being to examine the country from Loch Linnhe to Inverness, as to the practicability of making an inland navigation; and expressing a strong desire to see Mr. Watt's earlier survey of that district, in order by it to correct his own observations. His letter* concludes:—"We cannot spare you yet; you have done much good, and you must do more still. I cannot positively insist upon your personally making good the Spanish compliment, 'Live a thousand years,' but I may safely presume that your name will deservedly live for ever." "I have so long accustomed myself," he adds in a subsequent letter,† "to look with a degree of reverence to your work, that I am particularly anxious to learn what occurred to you in this business while the whole was fresh in your mind. * * The object appears to me so great and so desirable, that I am convinced you will feel a pleasure in bringing it again under investigation; and I am very desirous that the thing should be fully and fairly explained, so that the public may be made aware of its extensive utility. If I can accomplish this, I shall have done my duty; and if the project is not executed now, some future period will see it done, and I shall have the satisfaction of having followed you in promoting its success." In 1802 also he again writes to Mr. Watt that he had found an abstract of his Report published in a Report which Dr. Anderson made to the Lords of the Treasury:—"I believe it is yours," says Mr. Telford, "because it is just and masterly; and I have introduced in my report your general description, plainly saying that it could not be so well told in any other words."

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* To the same, 9 April, 1774.

† Mr. Rennie to Mr. Watt, 19 May, 1793.

Mr. Telford says that, on comparison, he found the whole of Mr. Watt's statements in his survey "particularly correct, except in the fall from Loch Oich to Loch Ness, where we differ a few feet; but the states of the water in the Lochs make some difference, and the only bad weatherI experienced was during this part of the survey, so that I am not positive that I am right. I had not time to prove the levels, nor is it of much moment; the height of the water in Loch Oich above the tideway is 100 feet, as near as may be."* To which Mr. Watt replied:—"As we agree upon the level of Loch Oich the summit, any difference of level elsewhere cannot materially affect the estimates, as the feet of lockage will remain the same. The mistake may, however, be mine, as my levels were not repeated."†

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* Mr. Telford to Mr. Watt, 6th December, 1801.

† Mr. Telford to Mr. Watt, 17th December, 1801.

The depth of water recommended by Mr. Telford was 22 feet. That of the canal as executed was in most parts 15 feet; although the bridges and locks were prepared on a scale to admit of that being increased, should it ever be found advisable, to 20 feet. Mr. Telford introduces a long extract from Mr. Watt's report, with the following observations:—"In the year 1773, the Trustees for the Forfeited Estates employed Mr. Watt to make a survey of this track, which he did, and furnished them with a report and estimate of the expense of making a canal of ten feet water. This report is so able and just, that had I considered that size of canal as most advisable, I should have adapted the calculations of the expense to the present day, and mentioned some alterations which have taken place in the country since his survey was made, and should have recommended the survey to your Lordships' attention. But Mr. Watt's views were merely to ascertain how far a navigation of any sort was practicable, and therefore he fixed upon ten feet of water as an assumed standard to enable him to make his estimates. I lose, therefore, the benefit of his particular calculations; and I am under the necessity of departing, in some instances, from his line of canal, especially at the entrances into the lochs and tideways, in order to obtain a greater depth of water; but I have followed him wherever the circumstances would permit; and I cannot resist the introducing his general description of the country through which the navigation is proposed to be made, because, after having examined the whole with care, I find it to be so correct, that I could only repeat the same descriptions and dwell upon the same points." Their levels agreed within one foot.—See p. 42 of the Report. In his Report,* Mr. Watt mentions that he confined his estimates to a canal of ten feet depth of water, because he knew of none that had been executed upon a greater scale, and because his views in making the survey were principally directed to those dimensions. "It is sufficient," he adds, "in a first survey, that the possibility is established, and the expense of one mode of communication is nearly estimated, which I flatter myself I have done. If from my observations the making any communication should appear an eligible scheme, the matter may be minutely examined, and the opinions of other artists obtained, concerning the best mode of execution."

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* Mr. Telford to Mr. Watt, 3d May, 1802.

† Mr. Watt to Mr. Telford, May 9, 1802.

It is curious, if only by way of contrast with the practice of the present day, to record the rate of payment at which the skill and exertions of a man endowed with Watt's powers of mind were then obtained. The Strathmore survey of 1770 may be taken as a specimen. On that occasion he was actively engaged in travelling and in field operations for forty-three days, usually from eight or nine in the morning till seven or eight at night, during most inclement weather, with piercing cold, and frequent and heavy falls of snow and rain; and his exertions so much exhausted his strength, as to render him, to use his own words, "unable for some time to apply himself to any other business that required attention." His charge for that work was 80*l.*, or about 1*l.* 17*s.* per diem, *inclusive of all his expenses of travelling and living.* For the preparation of the Report and directing the execution of the map which accompanied it, he was paid the further sum of 30*l.*—an almost equally insignificant recompense for the mere amount of time and labour bestowed, independent of all considerations of superior knowledge, accuracy, and sagacity.

That the rate of remuneration of civil engineers did not rise in any very rapid ratio in the latter part of the last century, appears from a letter of Mr. Watt in 1791, in which it is incidentally mentioned that Mr. Rennie, "who is in considerable fame, and, I suppose," says Mr. Watt, "as well paid as any of his standing, has two guineas a-day when employed as an engineer;" in addition, however, it is to be presumed, to his travelling expenses and other "costs and outlays," which was not the case with the smaller rate of pay of Mr. Watt in 1770.

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* Third Report on the Survey of the Coasts of Scotland, ordered to be printed 14th June, 1803, Appendix, p. 32.

CHAPTER XVI.

PHILOSOPHICAL PROBLEMS—TIME-PIECES—MICROMETER AND DIVIDING-SCREW—SURVEYING QUADRANT—BAROMETERS—MICROMETERS FOR MEASURING DISTANCES—HISTORY OF THE INVENTION OF MICROMETERS—SIR DAVID BREWSTER—DE LA HIRE—ROCHON—MASKELYNE—DEATH OF MR. WATT'S FIRST WIFE.

BESIDES all his surveying and civil-engineering, and the manifold alterations he devised in both his condensing and his wheel engines, Mr. Watt bestowed, during the years of which we have now been speaking, in concert with his friend Small, a good deal of thought on various other ingenious mechanical contrivances, which supplied pleasant amusement to their inventive and reflective brains. "We have abundance of matter to discuss," says the great engineer; though the damned engine sleep in quiet!"* "The French, you know," says Small, "offer large præmia for time-keepers. Were I idle, I should try to win one of these. But physic exhausts my whole faculties, and pays but indifferently. I am so made that I suffer no fatigue from thinking ever so long and attentively on a subject in which I can get forward; but if I am absolutely puzzled, and see no clue, my head turns round, and I speedily become more tired than a galley-slave. Physic very fortunately furnishes abundance of these profitable points."† "I have perfected my clock with one wheel of nine inches diameter, which is to tell hours, minutes, and seconds, and strike, and repeat, and be made for thirty shillings."* And again, "My clock of one wheel, that shows hours, minutes, and seconds, and strikes the hours and repeats them, is nearly finished. The striking and repetition are good, the rest is gimcrack."†

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* 7 November, 1772.

† 5 October, 1770.

"You wrote me before," says Mr. Watt,‡ "of your clock with one wheel. Did I ever mention to you a striking part, regulated by a balance pendulum with live scapement, which had only one wheel?" But some months later,§ "Everybody," says Small, "is too much engaged for the prosecution of schemes, so that even my clock is not prosecuted, and I have only one, which I cannot send to you;"—I have just ordered a pendulum clock to be made with no wheel at all;"‖—and, "when my clock with one wheel," he afterwards adds,¶ "was finished, I found it too complicated, and have now got one with no wheel, and only one sector with seventy-five teeth. It strikes, repeats, shows hours, minutes, and seconds, and goes eight days, with the usual descent of the weight. This is to be ranked in mechanics as riddles and rebuses are ranked in poetry."

On which comes this comment of the sagacious Watt:—"As to clocks, I do not fully conceive how you can make yours go eight days with the ordinary descent of the weight, unless by pulleys or something equivalent, which would only be a quibble upon a wheel;"**—thus answered by the inventor:††—"there is no quibble in my clock, and we have now found a tolerable workman for the execution of it. One is now making, which will show with much more accuracy than any other clock has hitherto done, the spheric phenomena relating to astronomy, sidereal and mean time, hours, minutes and seconds, with only one wheel and one sector. It will also strike and repeat the hours. The wheel has 72 teeth and the sector 75 only;"—"I have had a new scapement made for watches, of such marvellous virtue, that if the maintaining power is quadrupled, or decupled, the number of the vibrations will be lessened, but not above ten in twenty-four hours." * And—"I have taken out a patent for improvement on clocks and other time-pieces, and want you vastly to help me to draw up the specification, which must be given in soon. I have made a church-clock, consisting only of one wheel of 126 pins, and one sector of 75 pins, and a hammer, with a scapement for the sector and another for the hammer. It strikes the hours, shows hours, minutes, and 20th parts of minutes, and goes eight days. And I have given drawings of a pocket-watch, which is to consist of one wheel and two sectors, and is to show hours, minutes, and seconds, and to have only 142 pins in the whole watch, and to have no chain nor fuzee, the kind of scapement rendering them unnecessary. But I have had hitherto villainous bad workmen. The axis of the pendulum of my clock is a cylinder, and rolls upon curves, which render the vibrations isochronous, and it has two rolls for one impulse." †

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* 14 February, 1771.

† 16 December, 1771.

‡ 24 December, 1771.

§ 11 July, 1772.

‖ 16 November, 1772.

¶ 3 December, 1772.

** 17 January, 1773.

†† 27 January, 1773.

"A patent," he again writes,‡ "has been taken out for my clocks and watches, and there is reason to hope they may become an article of commerce. I am ready to make over to you all my interest in the patent, provided that can be done so as to benefit all concerned, which, if you can be established in this country, might be the case."

"As to gimcracks," writes Mr. Watt,§ "I have contrived a a new micrometer, made by drawing two converging lines upon glass. I believe from trial it will answer. I mentioned a dividing-screw; it has a wheel fixed upon it with 150 teeth and only 1¼ inch diameter: it is moved any portion of a turn or number of turns by a straight-line rack, the teeth of which fit it, without shake, and is moved by the hand or foot. It divides distinctly an inch into 400 equal parts." Of the micrometer, we shall soon give a full history. "As to your doubts about the screw," he writes

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* 15 March, 1773.

† 27 October, 1773.

‡ 29 March, 1774.

§ 24 November, 1772.

to Small, "I intend to annihilate them when I see you:"—"my dividing-screw can divide an inch into 1000 tolerably equal and distinct parts on glass;"—"I had occasion to use my last dividing-screw for the first time the other day. It divided 9 inches into 20ths, and did not err the $\frac{1}{200}$th of an inch in the whole 9 inches. I did not find that there was the least inequality among the divisions, though I subjected them to the most severe trial, and I have found a way by which I can divide a foot into $\frac{1}{1000}$ths of an inch without erring above $\frac{1}{200}$th of an inch in the whole length, and the divisions shall be equal among themselves; so that I reckon that machine exceeding near perfect, and find it very useful, as it saves much needless compass work, and, moreover, can divide lines into the ordinates of any curve whatsoever." "I rejoice in all your improvements," replies Dr. Small,* but have many optical difficulties that lessen my confidence in observations made with the most accurately divided instruments. For example, no optical instrument hitherto constructed, catoptric or dioptric, or catadioptric, produceth an exact copy of any object; so that all the visible points of every object of sensible apparent diameter are represented in the field of the instrument in situations in relation to each other very different from what they ought to occupy, &c., &c. The *unsteady* refractions of light passing through the atmosphere are also vile things; not those mentioned by astronomers only, but others I will show you when we meet."

"I am making a new surveying quadrant by reflection," writes Mr. Watt,† "having the uses of a semicircle as taking angles to 180°; the principle, that of Bird's octant, in which the objects are only once reflected. In this I am making, the fixed glass stands at 45° to the first radius; and by shifting the place of the eye, the head is never in the way. I am going to make another altogether of glass, with nonius of the same."

On which Dr. Small observes:—"I remember to have much admired your schemes about improving instruments for measuring angles by reflected light. Dollond has lately, as I have heard, made some inconsiderable but saleable alterations of Hadley's Quadrant, as it is called, though the invention is Newton's, which you no doubt know."

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* 29 March, 1774.

† 17 January, 1773.

"I am attempting the improvement of telescopes, and still more anxiously of microscopes, because the present microscopes deceive their users; but I find it very difficult to procure good lenses. Could you make an achromatic lens of half an inch focal distance? Dollond's patent is out."

In return, says Mr. Watt: *—"I have invented two problems for clearing the observed distance of the moon from a star of the effects of refraction and parallax; one trigonometrical, by Mercator's sailing,—the other instrumental, by a sector having a line of chords on each limb and a moveable portion of a circle of the same radius, which, if of three feet, the problem may be solved to ten seconds. If I have time I will make a model of it, and bring it when I come. Moreover, I can solve the same problem according to Dunthorne's method, by two lines of natural cosines upon a sliding rule." "I like your astronomical instrument," is the immediate reply;†—" All the problems of astronomy and of sailing might be sufficiently well solved, especially the last, and I have often wondered such instruments were not in use. Harrison's watch begins to make a great noise again. The King has had it tried under his own inspection, with vast success. Sooner or later it will eradicate astronomy from navigation, which is unlucky for your inventions:" and, some months later,‡ "As to the quadrant, if it is intended only to perform tolerably, and to be portable, it is good; but you do not mean, I suppose, to rank it with quadrants of some other forms. And how do you intend to keep the parts of it in the same, or in parallel planes, and to contrive that your line of chords should constantly be the base of an isosceles triangle? This last is not very difficult; but the other, I fear, is. Then you must have a faithful table of

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* 7 March, 1773. † 15 March, 1773.

‡ 16 October, 1773.

chords, which is still to be formed; for the published ones are not correct."

Two new barometers contrived by Dr. Small he thus describes: "In one of my barometers the scale floats within the tube, and is of such specific gravity, and of so accurately expansile matter, that it constantly shows the weight of the atmosphere correctly. This is difficult to be made. The other is very easy. The bason is large; a float of metal, with a hole for the tube in its middle, lies upon the surface; a scale stands upon the float, and expands and contracts just as much as mercury. You can easily imagine how both may be rendered portable:"—on which Mr. Watt's brief commentary is:—"I admire your expansile scale, the idea of which I had before, but had none of the possibility, as I know nothing that expands so much by heat as quicksilver, unless Newton's metal does it. I have objections to the floating, which I defer to meeting."

In Mr. Watt's survey of the Tarbert and Crinan lines, for a navigable canal, in 1771, he used the micrometer for measuring distances, which he had then invented; and of which, as well as of the circumstances which led to his employment and improvement of it, he has left the following account.

Micrometer for measuring Distances.

"This instrument was contrived about the year 1770 or 1771. I know I used it in the surveys of the Crinan and Gilp and the Tarbert intended canals, and also in the survey of the canal from Inverness to Fort William, now called the Caledonian Canal. The former survey was in 1772,* and the latter in 1773, and it was in 1772 I showed it to Mr. Smeaton.

"The instrument I used was a telescope with an object-glass of twelve inches and an eye-glass of one and a half inch focus;

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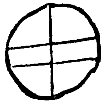
* This date, as has been mentioned, is that of the completion of the Report; the actual survey took place in 1771.

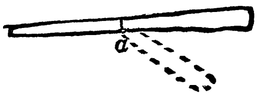
consequently magnifying eight times. In the focus of the eye-glass there were placed two horizontal hairs, (see margin,) and one perpendicular hair. The horizontal hairs were about one-tenth of an inch distant from each other, and as strictly parallel to each other and at right angles to the perpendicular hair as I could make them. A rod being placed upright at twenty chains distant, or any other convenient distance, on level ground, an index consisting of a round disk of about eight inches diameter painted white, with a horizontal line of one inch wide painted on its horizontal diameter with vermilion, was fixed upon the rod about one foot from the ground, and another similar index was moved up and down the rod, until upon looking through the telescope the two horizontal hairs covered the red stripes on the lower and upper indexes, the telescope being turned on its axis until the perpendicular hair was parallel to the rod. The indexes being thus covered by the horizontal hairs accurately, the upper index was fixed to the rod, and the distance between the middle of the red stripes on the two indexes was divided upon the rod into twenty parts, representing so many chains, which with the instrument I used were upon the rod about four and a half inches each, and for distances exceeding five chains this division into equal parts was sufficiently accurate; but for shorter distances it is not strictly so. I therefore fixed a pin at every chain, and holding up the rod at each of them made the necessary correction, and as the focus of the object-glass is also affected by the distance, it is proper to adjust the eye-glass to it at each station.



"The divisions on the rod being marked with the number of chains they represent, it was only necessary to send an assistant with the rod to any place the distance of which was wanted to be measured, and, by signs, to make him move the upper index up and down until the two horizontal hairs covered the red stripes on the upper and lower indexes; the divisions on the rod then showed the distance, which I found could be ascertained to within less than one-hundredth part of the whole distance, and with a higher magnifying power could be done proportionally more accurate. The rod I commonly used was twelve feet long, and consequently could measure thirty chains; but by sliding another rod upon it so as to lengthen it, I measured greater distances; and when still greater were wanted I stretched a tape horizontally, and, turning the telescope on its axis, made the single hair parallel to it, fixing one index at the end of the tape, and sliding the other along it until it subtended the distance between the wires. I then measured the subtended tape with the rod, and so ascertained the distance; but this expedient I rarely had recourse to, the distances I generally had occasion to measure rarely exceeding half a mile, or forty chains.

"It is plain that this instrument possesses the advantage of measuring all distances with equal accuracy, until the imperfection of vision at great distances interferes, as the scale on which they are measured expands with the distances; and in uneven ground it possesses more accuracy than the chain, and is very valuable in measuring distances from one hill to another, and across bays of the sea, where the chain cannot be used. This I experienced in the survey of West Loch Tarbert, the northern shore of which is very much indented, and so rocky that it is scarcely possible to measure a few chains in a straight line upon it.

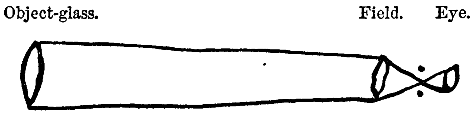
"I showed the instrument to all my friends at the time, and among others, to Mr. Smeaton, as I have mentioned; and used it publicly in my surveys, and it was consequently known to many people, though not published in print. A Mr. Green, in 1778, applied to the Society of Arts, for a premium for the same invention, which Mr. Smeaton apprised me of, and also informed the Society of my claims; in consequence of which I was desired to attend the committee, where I informed them of what I had done, and at what time. Yet the Society thought fit to award Mr. Green the premium, though his invention or use of the method was posterior to mine,—I suppose because he had used an instrument of higher magnifying power, viz. forty, and consequently had been able to measure greater distances, and, as was said, with greater accuracy. I made no further reclamation, as I perceived it was not in that court I could obtain justice; and, as I abhor paper war, I did not apply to any other, though there were people then living who could have attested my use of it.



Section.

"Another micrometer, with a prism, I invented, I think, about that time It consisted of a thin prism almost parallel (say of one degree or two.) This prism was cut by a diamond into two parts, which, when they were fixed in the same plane, refracted all the rays which passed through them equally; but one of them remaining fixed, and the other moving on a centre at *a* (according to the pricked line,) would refract that portion of the rays which passed through it more than those which passed through the fixed part; and being fixed in the focus of the object-glass of a telescope, two images were formed of each object, by which its diameter could be measured. An index and divided sector of a circle served to measure the comparative refractions. This instrument I made with the sector and radius of wood, and gave it to Professor Anderson, of Glasgow College,- and I suppose it is still among his apparatus, which he left to a public institution. The Abbé Rochon afterwards (1783) published a description of some micrometers with prisms, but I think they were upon somewhat different principles in their construction.

"The cross-hair micrometer, as described, leaving me too much in the power of my assistants, where the distances were greater than permitted me to read off the number of chains on the rod myself, I set about another about 1772 or 1773, which consisted of a telescope with an object-glass of a long focus, say three or four feet: this was placed in a tube with a slit in one side of it nearly as long as the focus of the telescope, and the object-glass being fitted to a short tube which slid from end to end of the slit, could be moved backwards and forwards by means of a piece of metal fixed to the short tube and coming out through the slit: a glass of six to nine inches focus was also fixed in the outer tube, in the nature of what is called a field-glass, and to this was added an eye-glass with a cross-hair piece in its focus; thus—



"Now it is evident that if the object-glass be moved nearer the field-glass, their common focus will be shortened, and the image at the cross-hairs diminished, proportionably, until, when the glasses come into contact, their common focus will be shorter than that of the field-glass alone; and two indexes fixed upon a rod being subtended by the cross-hairs at any given distance, the same rod with its indexes being removed nearer the observer, upon sliding the object-glass nearer the eye they may again be subtended by the cross-hairs; a scale on the side of the tube will show the comparative distance they have been removed, and the distance of the first being known, that of the second will also be so. This scale would not, however, be a scale of equal parts, but one which could easily be laid down.

"I made a rough model of this instrument at the time, but have never completed it, having been mostly since in a line of business where such instruments were unnecessary. I described it, however, to several of my friends at the time, and among others to the late Mr. Ramsden; but whether it has been thought of by any one else, or the problem published, I am ignorant."

Sir David Brewster, at a later period, but without any knowledge of the instruments which had thus been contrived by Mr. Watt, invented an improved micrometer with a moveable object-glass, which is described in his 'Treatise on New Philosophical Instruments in the Arts and Sciences, with Experiments on Light and Colours.'* But in a review of that work in the 'Bulletin de la Société Philomathique,' for 1814, M. Arago having pointed out that the invention of a moveable object-glass for separating, optically, a pair of wires fixed in the focus of a telescope, had been made by M. de la Hire more than a century before, as is mentioned in the 'Mémoires de l'Académie des Sciences' for 1701,—"I have since," says Sir David, in writing to Mr. Watt, with the candour by which that eminent philosopher has always been honourably distinguished, "examined M. de la Hire's works, and find that M. Arago is perfectly correct. This fact therefore deprives you and me of all original merit in the invention of the principle, although you were as little acquainted with De la Hire's labours as I was with yours. The idea, however, of converting it into a general micrometer, of applying it to the *divided* object-glass (which is decidedly its best form), and of converting a Gregorian or Cassigrainian telescope into a micrometer without any additional lens or mirror, is still mine."†

For a summary of the dispute as to the invention of *prismatic* micrometers, we may refer our readers to M. Mathieu's learned note on Delambre ('Histoire de l'Astronomie au dix-huitième Siècle,' pp. 645-652, ed. 1827.) There the priority is attributed to Rochon, who presented the Academy of Sciences with a description and a specimen of that sort of instrument in January and February, 1777, and in April following reported to the same learned body the measurements of Mars, of Jupiter, and of Saturn with his ring, which he had obtained by its aid.

Maskelyne, who, in December 1777, presented his prismatic micrometer to the Royal Society, produced an attestation by Dollond that he had constructed it for him in the previous year, and taken it to the Observatory at Greenwich in August, 1776.‡

To both of those dates Mr. Watt's invention appears to have been antecedent by several years; although of it we may say, as M. Mathieu has done of that of Rochon, "Cet ingénieux instrument ne reçut pas, dans le temps, tout l'accueil qu' il méritait."

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* Edinburgh, 1813, 8vo.

† Sir David Brewster to Mr. Watt, December 12, 1816.

‡ See the 'Philosophical Transactions' for 1777, vol. lxvii. pp. 799-813, &c. See also Boscovich's 'Account of a new Micrometer and Megameter,' *ibidem*, pp. 789-798.

"The Abbés Boscovich, Fontana, Rochon, Maskelyne," wrote Dr. Patrick Wilson to Mr. Watt, in 1778, "are a very creditable junto of philosophers, who are at present drawing some attention as inventors of a prismatic micrometer. My father and I feel a wish of seeing your name added to that band of improvers. Your invention, though very little known, was several years prior to any of theirs. If you choose to assert this priority by any publication, it will give us great pleasure to contribute our evidence in your favour;"—and to the same effect, and at the same time, Dr. W. Irvine:—"Pray have you seen the last volume of the Transactions? You must surely know that it contains the description of a certain micrometer, that shall be nameless, made by one J. Watt six or eight years ago, and which has been in Macfarlane's Observatory in Glasgow for several years past. Would you not think it proper that the said J. Watt should claim this discovery? And as the authors of these papers in the Transactions have brought witnesses, he might bring Dr. Reid, Dr. Wilson, Pat. Wilson, G. Hamilton, &c., who are ready and willing to attest the same, and who are surely as respectable as Pat. Dollond and —— Aubert; and to make the whole still stronger, I should imagine you could have no objection to join in the attestation. You may perhaps despise such unprofitable inventions; but to others they will procure fame, and perhaps fortune."

One other "gimcrack," and we have done with the long list of useful and ingenious contrivances with which it had been the pleasure of the great engineer, up to this period, to occupy his few hours of leisure;—"I have invented a drawing-machine," he says,* "the board horizontal, the index almost as long as you please, and consequently the size of the picture large; a telescopic sight; no specula; the whole being performed by a most simple joint. When the index does not exceed two feet long, the instrument and apparatus consist of a box 14 inches long, 1¼ deep, and 4½ inches broad, which opened is the drawing-board, and contains the apparatus, except a light wooden tripod head for the pocket, and a staff for the hand, of the ordinary size. By help of this machine I can draw from an eminence a draught of level grounds that shall be a true projection of them, and shall measure by a scale of equal parts. It also draws all kinds of perspective draughts, reduces maps, &c., the board being always horizontal, whether the objects be vertical or not."

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* To Dr. Small, 11 December 1773.

Within a fortnight, however, came this reversal of the verdict thus pronounced:—"I caused to be made a part of the machine I mentioned in my last; it has only one fault, which is, that it will not do, because it describes conic sections instead of right lines;"* and although there can be no doubt that by a little further labour on the part of the inventor this difficulty would have been overcome, yet events of more importance soon occurred, which seem to have put a stop to the career of "gimcracks," in which he and his friend Small had so long and cheerfully been running a race together, and which led the latter to remark to his friend,—"You might live by inventing only an hour in a week for mathematical-instrument-makers."

The termination of Mr. Watt's labours as a civil engineer was an abrupt one, accompanied—and indeed in some measure caused—by a melancholy event. Having been suddenly recalled from his survey of the Caledonian Canal in the autumn of 1773 by the intelligence of the dangerous illness of his wife, he had the deep grief of finding on his return home that she had died, after having given birth to a still-born child. Mrs. Watt is described as having been a very amiable person, whose gentle counsels and uniform good temper had often sustained her husband's hopes and animated his exertions, under the depressing circumstances of indifferent health, narrow means, and variable and often desponding spirits; from all of which he then suffered in no ordinary degree. By relieving his mind as far as possible of other care, and thus affording it the undisturbed leisure required for study and exertion in his various pursuits, she might even be said to have been of material, though, of course, subsidiary service to him in the progress of his great invention. She earnestly encouraged the hopes which he founded upon it; and even when these seemed for a time to be quite overthrown, her buoyant spirits did not sink, nor did her cheerful faith fail; but she wrote to him with truly feminine fortitude,—"I beg you would not make yourself uneasy, though things should not succeed to your wish. *If it*" [the new steam-engine] "*will not do, something else will. Never despair.*" *

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* 24 December, 1773.

"The few years," says Miss Campbell, "of his union with Miss Miller passed in uninterrupted domestic happiness. Of her untimely death, and the beautiful composure of mind, and affecting tenderness for her husband and children, that she displayed in her last moments, my mother never could speak without tears."

The agony of grief which he suffered on losing so judicious, so beloved, and so faithful a friend, sufficiently appears from those of his letters of that date which have been preserved; although some others, it is to be regretted, appear to have been lost or destroyed, probably in consequence of containing no allusion to anything but his private sorrow. Of one, which survives only in the form of an undated fragment, addressed to Dr. Small, but evidently belonging to the period in question, the expressions are gloomy indeed;—more so, happily, than the habitual resignation of its writer to the will of the Supreme Disposer of all events seems ever to have permitted him to repeat. "Let us," he writes, "rejoice in our youth, for age is dark and unlovely, and in the silent grave there is no joy, at least that we know of;—vive, et vale." And again:—"You are happy, Small, that have no such connection. Yet this misfortune might have fallen upon me when

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* August 9, 1768.

I had less ability to bear it, and my poor children might have been left suppliants to the mercy of the wide world. I know that grief has its period; but I have much to suffer first. I grieve for myself, not for my friend; for if probity, charity, and duty to her family can entitle her to a better state, she enjoys it. I am left to mourn. * * Let me leave this tale of woe."

"Would that I might here transcribe," said Arago, "in all their simple beauty, some lines of the journal in which he daily recorded his inmost thoughts, his fears, his hopes! Would that you could see him, after this heavy affliction, pausing on the threshold of that home, where 'HIS KIND WELCOMER' awaited him no more; unable to summon courage to enter those rooms, where he was never more to meet 'THE COMFORT OF HIS LIFE!'"

Of the four children who were the issue of Mr. Watt's marriage with Miss Miller, two died in infancy; one daughter married a Mr. Miller of Glasgow, but died early, leaving issue a son and two daughters, (now all dead, the daughters having left issue); and the only son of that family who attained manhood was the late Mr. James Watt, of Aston Hall, who long survived his father as his respected representative, and died, unmarried, in 1848.

CHAPTER XVII.

DEPRESSION OF SPIRITS—INSOLVENCY OF DR. ROEBUCK—FORMATION OF PARTNERSHIP WITH MR. BOULTON—TRANSFERENCE OF THE NEW ENGINE TO SOHO—PROLONGATION OF PATENT OF 1769—DEATH OF DR. SMALL—NOTICES OF HIS LIFE, TALENTS, AND VIRTUES—PROGRESS AND PROSPECTS OF THE NEW MANUFACTORY—ARTICLES OF PARTNERSHIP.

This last most grievous calamity put the finishing stroke to the long series of adverse circumstances by which Watt had been oppressed. For years previously he had complained of frequent violent headaches, and almost constant bad health; of what he called laziness, stupefaction, and confusion of ideas, which no doubt meant the mental weariness arising from severe and anxious over-exertion; of the hatefulness of the employment of land surveying, to which he had then become a slave; of his detestation of making bargains, or settling accounts, or forcing workmen to do their duty; so that "I greatly doubt," he says in 1770, "whether the silent mansions of the grave be not the happiest abodes." "I am heart-sick of this country," he writes, after the loss of his wife, to his sympathizing friend Dr. Small, "I am indolent to excess, and, what alarms me most, I grow the longer the stupider. My memory fails me so as often totally to forget occurrences of no very ancient dates. I see myself condemned to a life of business; nothing can be more disagreeable to me; I tremble when I hear the name of a man I have any transactions to settle with. The engineering business is not a vigorous plant here; we are in general very poorly paid. This last year my whole gains do not exceed 200*l.*, though some people have paid me very genteelly. There are also many disagreeable circumstances I cannot write; in short I must, as far as I see, change my abode. There are two things which occur to me, either to try England, or endeavour to get some lucrative place abroad; but I doubt my interest for the latter. What I am fittest for is a surveying engineer. Is there any business in that way?" And, about the same time, it appears Dr. Roebuck had mentioned Mr. Watt having had an intention of passing the winter in France; to escape, doubtless, from the sorrowful associations that now pressed upon him in his own country.

These circumstances all concurred with the disastrous state of affairs at Borrowstoness and Kinneil, to hasten the final settlement of the agreement with Mr. Boulton and Dr. Small. But it was now evident, since Roebuck had besome insolvent, and therefore unable to be any longer a partner in the proposed manufacture, that instead of one-half of his two-thirds of the patent of the engine, or one-third of the whole patent, as originally intended when that agreement was entered into in 1769, the whole of his interest would have to be purchased from him or his creditors. We have already seen that Boulton and Small were not more desirous of benefitting Watt, than Watt was of benefitting Roebuck; and also, that all four were anxious to see the engine prosecuted to completion, and its merits tested by actual performance on a great scale, none of them, (and, least of all, the inventor,) estimated the invention, as then attempted to be carried out, as of any very high pecuniary value. In this view, it fortunately happened, that Roebuck's creditors most fully concurred; "none of his creditors," writes Watt to Small,* "value the engine at a farthing;" and this uncomplimentary estimate,—at which we now so well may marvel, and the creditors might soon afterwards have mourned,—was really of the greatest service in hastening the progress of the transference of the property.

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* 25 July, 1773.

On terms satisfactory at the time to Dr. Roebuck, and which consisted in part at least of Mr. Boulton releasing him from a debt of 630*l.* due to him by the Doctor, and of the payment by Mr. Boulton of a further sum of 1000*l.*, this transference at last took place, to Mr. Boulton alone; Dr. Small having by that time otherwise engaged all of his available funds. The 1000*l.* paid were to be the first 1000*l.* of profit, (without repayment of any already sunk,) that might arise after the commencement of the partnership of Boulton and Watt. And in 1773 Mr. Watt and Dr. Roebuck executed a mutual discharge, which, as an interesting document in the history of the modern steam-engine, we shall here give entire:—

"In the year 1767, Doctor John Roebuck at Kinneil, entered into partnership with James Watt at Glasgow, to verify and carry into practice an improved fire-engine invented by the said James Watt. Doctor Roebuck was to pay a debt of 1000*l.* incurred by the said James Watt in making the experiments tending to the invention of the engine, and also to pay the expense of the patent and further experiments.

"James Watt was to attend and conduct the experiments, and assigned to the Doctor two-thirds of the property of the said invention, retaining one-third for his own use.

"Dr. Roebuck has paid the thousand pounds, but the expense of the other things has been principally paid by James Watt.

"In consideration of the mutual friendship subsisting between Dr. Roebuck and myself, and because I think the thousand pounds he has paid more than the value of the property of the two-thirds of the inventions, I hereby take upon myself all other sums I have laid out or paid upon it, also all other debts I have contracted upon that head, relieving the Doctor from the same, and meaning this as an absolute discharge for all sums he may have been owing me before this date.

"JAMES WATT.

"Kinneil, May 17th, 1773."

"Having examined the above narration of facts, I acknowledge the same to be just, and hereby discharge the account.

"John Roebuck.

"Kinneil, May 17, 1773."

Thus, in the summer of 1773, Mr. Watt found himself at liberty to remove from Kinneil, where they had long been lying useless, and "perishing" from "long exposure to the injuries of the weather," the iron works, cylinder, and pump, of the condensing engine partly erected there three years before. Those "disjecta membra" were then packed up and sent off to Soho, where a boiler was awaiting them, destined to inspire them with new life and movement; but it was not till after another year that they were followed by Mr. Watt, who had in the interval made his survey for the Caledonian Canal, and had suffered the loss, in which it so dismally terminated, of his much-loved wife.

Early in April 1774, he writes to Dr. Small, "I begin now to see daylight through the affairs that have detained me so long, and think of setting out for you in a fortnight at furthest;"—and, early in May, "I have persuaded my friend Dr. Hutton, the famous fossil philosopher, to make the jaunt with me, and there are some hopes of Dr. Black's coming also." The next four or five months were passed in continuous though still partially futile attempts to construct a satisfactory wheel-engine, and in more successful ones to make the condensing engine do some good work. By the end of October, Mr. Watt was able to send his friend Roebuck such a report of the latter, that Dr. R. replied,* "You have now effectually established the justness of the principles on which your machine is constructed, and the generous and spirited gentleman you are connected with will never suffer it to fail for want of exertion to carry it into execution." He was also able to cheer the heart of his aged father, in his lonely home at Greenock, by writing to him, from Birmingham,† "the business

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* 12 November, 1774.

† 11 December, 1774.

I am here about has turned out rather successful, that is to say, that the fire-engine I have invented is now going, and answers much better than any other that has yet been made; and I expect that the invention will be very beneficial to me."

The comfortable results which led to these improved hopes, had been obtained, it must be recollected, with a cylinder made at Carron so far back as 1766, and not very truly bored, although the best which that manufactory could turn out at that time; and Carron had the best boring-mill, for cannon and the cylinders of the old sort of steam-engine, then known. "It was only intended," says Mr. Farey, "for boring cannon; but they bored barrels [of pumps] and cylinders [for atmospheric engines] by it occasionally. In the course of a few years, this mill proved too small to execute the work which their trade required, and in 1769 Mr. Smeaton made them an entire new boring-mill for guns, and another for cylinders."*

But Mr. Boulton, encouraged by the favourable results already obtained, applied, early in 1775, for a better cylinder, to Mr. John Wilkinson, an eminent iron-founder at Bersham near Chester, who at that very time, probably in consequence of the great demand he saw reason to believe would arise for cylinders bored with exact truth throughout, introduced a new boring-machine which was an infinite improvement on the old one. "In the old method," says the same accurate author whom we have last quoted, "the borer for cutting the metal was not guided in its progress, and therefore followed the incorrect form given to the cylinder in casting it; it was scarcely insured that every part of the cylinder should be circular; and there was no certainty that the cylinder would be straight. This method was thought sufficient for old engines, but Mr. Watt's engines required greater precision.

"Mr. Wilkinson's machine, which is now the common boring-machine, has a straight central bar of great strength, which occupies the central axis of the cylinder, during the operation of boring; and the borer, or cutting instrument, is accurately fitted to slide along this bar, which, being made perfectly straight, serves as a sort of ruler, to give a rectilinear direction to the borer in its progress, so as to produce a cylinder equally straight in the length, and circular in the circumference. This method insures all the accuracy the subject is capable of; for, if the cylinder is cast ever so crooked, the machines will bore it straight and true, provided there is metal enough to form the required cylinder, by cutting away the superfluities."*

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* Farey, 'Treatise on the Steam-engine,' 1827, p. 291.

But, notwithstanding the improved cylinder, and those other aids of mechanism which could then be derived from the workshops of Soho and Birmingham, it was very evident that a long series of experimental trials was still requisite before the engine could be brought to such perfection as to render it universally available to the public, and, therefore, profitable to its manufacturers. In January, 1775, six years of the period named in the Letters Patent had already expired; and there seemed every probability of the eight that remained proving only sufficient to admit of a great outlay of labour, talent, and money, for the benefit of others who had exerted no ingenuity, incurred no risk, and displayed no perseverance.

The eminent counsel whom Mr. Watt consulted, suggested the surrendering up of the patent, and did not doubt that a new one would then be issued, granting the exclusive privilege anew from its date. Other friends recommended that an application should be made for an Act of Parliament extending the time allowed by the first patent, and this was the course which it was finally determined should be taken. The application met, rather unexpectedly, with very strong opposition, to which the great oratorical powers of "the immortal Burke" gave a dangerous importance. He, it is believed, was influenced by what he conceived to be, or what was represented to him to be, the claims of a constituent, and not by any more unworthy feeling of hostility to either Mr. Watt or his patent; but nevertheless he was led to support with all the power of his great name what he probably would afterwards have confessed to be a measure of gross injustice. Happily, the eloquence of himself, and the influence of his associates, failed of their intended effect; and, on the 8th of May, 1775, Mr. Watt had the pleasure of being able to write to his father, from London, the following letter:—

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* Farcy, p. 326.

"Dear Father,—After a series of various and violent opposition, I have at last got an Act of Parliament vesting the property of my new fire-engines in me and my assigns, throughout Great Britain and the Plantations, for twenty-five years to come, which I hope will be very beneficial to me, as there is already considerable demand for them.

"This affair has been attended with great expense and anxiety, and without many friends of great interest I should never have been able to carry it through, as many of the most powerful people in the House of Commons opposed it. It has been in Parliament ever since the 22d of February, which is a very long time to be kept in suspense.

"I shall be obliged to stay here a few days longer, after which I return to Birmingham to set about making some engines that are ordered; after which I intend to give myself the happiness of seeing you and the dear children. * * My warmest wishes and affection ever attend you; may God render your age comfortable is the prayer of your ever affectionate and dutiful son, JAMES WATT."

But while this affair was pending, and Mr. Watt was absent in London attending to it, another heavy blow had fallen upon him. This was the death of Dr. Small; the faithful and affectionate friend who had so long encouraged him in despondency, consoled him in misfortune, and aided him in attaining to the comparative prosperity which was now at last beginning to dawn upon him. "The last scene," feelingly writes Mr. Boulton to him in London,* "is just closed; the curtain is fallen, and I have this evening bid adieu to our once good and virtuous friend, for ever and for ever. If there were not a few other objects yet remaining for me to settle my affections upon, I should wish also to take up my lodgings in the mansions of the dead." "To pretend to offer you consolation," is Mr. Watt's reply, "under the weight of your present sorrow, I know to be in vain. I only beg leave to repeat to you the sentiments which that dear friend we lament expressed to me upon a similar occasion. It is our duty as soon as possible to drive from our minds every idea that gives us pain, particularly in cases like this, where our grief can avail nothing. Remember, my dear Sir, that our friend enjoys that repose he so much desired; and we ought not to be so selfish as to render ourselves unhappy by the perpetual recollection of our own misfortune, however great we may think it, for it is also irreparable and was inevitable." * * "Come, my dear Sir, and immerse yourself in this sea of business as soon as possible, and do not add to the griefs of your friends by giving way to the tide of sorrow. I again repeat that it is your duty to cheer up your mind and to pay a proper respect to your friend by obeying his precepts. I wait for you with impatience, and assure yourself no endeavour of mine shall be wanting to render life agreeable to you." "We have lost a most valuable friend," writes Dr. Roebuck on the same occasion, "a gentleman of extensive knowledge and learning."

Of Dr. William Small, whose family name is, perhaps, best known in the annals of science by his brother Dr. Robert Small's learned 'Account of the Astronomical Discoveries of Kepler,' we have few particulars to record beyond those which his correspondence with Mr. Watt supplies. But his early death has been commemorated and lamented by the pens of Keir, of Day, and of Darwin; and all the scattered notices that we have been able to collect attest the greatness of his talents and his worth. A native of Scotland, he was born in 1734 at Carmylie in the county of Angus, of which parish his father was minister; one of his ancestors being Mr. Thomas Small of Corrihall, whose armorial bearings were registered in the Lyon Office about 1680. Having been appointed Professor of mathematics and natural philosophy in the college of Williamsburgh in Virginia, he settled there for some years, and practised with great success as a physician; but coming home on account of his health and some business, he "preferred settling at home to returning to Virginia, as he never kept his health there." He was introduced to Mr. Boulton in 1765,—(the year, we need scarcely repeat, in which Mr. Watt made his memorable discovery of the separate condenser,)—by a letter from no less eminent a person than Benjamin Franklin; in which he is described as "one who is both an ingenious philosopher, and a most worthy, honest man;" and Lord Brougham has mentioned that he was the instructor in mathematics of the celebrated Thomas Jefferson. "He is," adds another of his friends in writing from London to Mr. Boulton, to announce his arrival in England, "a gentleman of great worth, integrity, and honour; and in the way of his profession he has the best recommendations of our most eminent physicians here." To the same effect is Mr. Keir's account of him, as "a gentleman of very uncommon merit," possessed of singular accuracy of ideas, and great acquaintance with men and things; "who, to the most extensive, various, and accurate knowledge in the sciences, in literature, and in life, joined engaging manners, a most exact conduct, a liberality of sentiment, and an enlightened humanity; being a great master in the exact sciences, and seeming to carry their regularity and precision into his reasonings and opinions on all other subjects." And in a MS. note on our copy of the work from which our last quotation is taken, and which was presented by its author to Mr. Seward, its former possessor has added:—"He had, I think, the greatest variety, as well as the greatest accuracy of knowledge, that I have ever met with in any one man."

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* [25 February, 1775.]

The passing of the Act of Parliament which ensured to Mr.

Watt and his assignees the exclusive right to "make, use, exercise, and vend" the steam-engines of his invention, now enabled him to arrange finally with Mr. Boulton the system on which their partnership and proposed manufacture of engines should be conducted. Of the great difficulties that still remained to be overcome in the further prosecution of their undertaking, we may form some faint estimate from the remarkable fact, that "at the period of the construction of the first steam-engine upon the new principles at Soho, the intelligent and judicious Smeaton, who had been invited to satisfy himself of the superior performance of the engine by his own experiments upon it, and had been convinced of its great superiority over Newcomen's, doubted the practicability of getting the different parts executed with the requisite precision; and augured, from the extreme difficulty of attaining this desideratum, that this powerful machine, in its improved form, would never be generally introduced. Such," adds the relator of this curious anecdote, the late Mr. Boulton,* "was at that period the low state of the mechanic arts, as fully to justify his opinion; but a school of workmen, in every relevant branch, was speedily and successfully instituted, and the forms and construction of the machine were perfected with a skill and accuracy till then unknown in the execution of large machinery."

The general curiosity that had begun to be excited throughout England as to the nature and comparative utility of the new engines, gave promise of at least a fair remuneration, if they could be successfully manufactured. So far back as 1771, Dr. Small had written to Mr. Watt,—"At present I am to tell you something of consequence, about which it will be proper to speak with Dr. Roebuck, to whom I offer my best respects. A friend of Boulton and me in Cornwall sent us word four days ago that four or five copper-mines are just going to be abandoned, because of the high price of coals, and begs me to apply to them instantly. The York Building Company delay rebuilding their engine, with great inconvenience to themselves, waiting for yours. Yesterday application was made to me, by a mining company in Derbyshire, to know when you are to be in England about fire-engines; because they must quit their mine if you cannot relieve them." And, in April, 1775, "There are several engines," says Mr. Boulton, "now wanted in Cornwall; some of the proprietors of mines are impatient to know the event of our Bill and the terms we will propose. I have ventured to say to Mr. Glover, (who was requested to wait upon us on that subject,) that we will undertake and contract to make an engine or engines capable of doing any quantity of work that shall be requested and described, for as little money as common engines will cost that are capable of doing as much work; and we will guarantee them to do that work with half the expense of fuel that common ones will require, provided we are allowed a sum that shall be equal to its further savings over and above the said half." In August or September, 1775, "Wilkinson hath been here, and says that all his neighbours are impatient to see the event of his engine. Some, he says, have suspended their new erections until his is finished; and all of them, he is sure, will have their engines altered, which he says will be a better trade than new erections, and that work alone will be sufficient for our lives." In March, 1776, "I rejoice at the well-doing of Willey engine," (that which had been made for Mr. Wilkinson,) "as I now hope and flater myself that we are at the eve of a fortune. I wish to see you at Soho as soon as possible; there are many things want you, and I find myself exceedingly hurried. People are daily coming to see the engines. Cornwall begins to inquire how we go on. I will reserve particulars until I see you." And, later in the same year, "I have an application for an engine from a distiller at Bristol, to raise 15,000 ale gallons per hour 60 feet high; I have another for a coal mine in Wales, another for a Mr. Langdale, of Holborn, a distiller, and another for Mr. Liptrap, at Mile End, a distiller." "If we had a hundred wheels ready made, and a hundred small engines like Bow engine, and twenty large ones executed, we could readily dispose of them." "We have a positive order for an engine for Ting-Tang mine, and from what I heard this day from Mr. Glover, we may soon expect other orders from Cornwall. Our plot begins to thicken apace, and if Mr. Wilkinson don't bustle a little as well as ourselves, we shall not gather our harvest before sunset. * * I perceive we shall be hard pushed in engine work, but I have no fears of being distanced, when once the exact course or best track is determined upon."

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* **Speech at the Public Meeting in Freemasons' Hall, in 1824.**

Yet, even then, the expectations of both the partners were very far indeed from being exorbitant, as to the profits to be derived from the important branch of manufacture on which they were preparing to enter. "It may be difficult," writes Mr. Boulton to Mr. Watt, in July, 1776,—more than a year after the Act of Parliament had been obtained,—"to say what is the value of your property in partnership with me. However, I will give it a name, and I do say that I would willingly give you two, or perhaps three, thousand pounds for the assignment of your third part of the Act of Parliament. But I should be sorry to make you so bad a bargain, or to make any bargain at all that tended to deprive me of your friendship, acquaintance, and assistance, hoping that we shall harmoniously live to wear out the twenty-five years, which I had rather do than gain a Nabob's fortune by being the sole proprietor.

"I would without hesitation have sent you the assignment and the article of partnership, had it been in my power; but Mr. Dadley, the lawyer, is suddenly called to London, and it cannot be had before his return; but if you want to show it to any of your friends, you may give them a copy of the following heads, which I have extracted from our mutual missives, and are to the best of my knowledge all that our articles contain:—

"1st. You have assigned to me two-thirds of the Act of Parliament, on the following conditions:

"2nd. I to pay all expenses of making all the experiments, and of obtaining the Act of Parliament, and all other expenses relative to the engine which were incurred before June, 1775;

and I am also to bear all the expenses of future experiments, and all such money is to be sunk by me, and not to bear any interest, nor be carried to my account with you; but the experimental machines are to be my property, as they are purchased at my expense.

"3rd. I am to advance all the stock necessary for carrying on the engine trade, for which I am to receive lawful interest.

"4th. The profits arising from the trade, after paying or deducting interest, (as in 3rd,) workmen's wages, and all debts owing by our engine trade, to be divided into three parts; you are to take one-third, and I to take two-thirds.

"5th. You are to make drawings, surveys, and give directions; the engine company to pay travelling expenses when upon business.

"6th. I am to take care that the books are kept accurately, and that they are balanced once a year; and I am also to assist in managing workmen, making bargains, or doing whatever we may jointly think is for the interest of the trade.

"7th. A book to be kept wherein are to be entered such transactions as are worthy of record, and, when signed by us both, to have the same force as our articles of partnership.

"8th. Neither of us to alienate our shares without the consent of the other; and if either of us should die, or be incapacitated from acting for ourselves, the other is to be sole manager, without control of heirs, executors, or assigns; but the books are to be subject to their inspection, and the acting partner to be allowed a reasonable commission for his extra trouble.

"9th. The contract to continue in force for twenty-five years from the 1st of June, 1775.

"10th. Our heirs, executors, &c., are bound to observe the contract.

"11th. In case we both die, our heirs, &c., to succeed upon the same plan.

"This is the essence of all that is contained in our articles of partnership; but, being fearful of losing the post, I have written in a great hurry, and have but ill expressed myself. I wish I had more time to tell you all the circumstances that have occurred in the engine trade, but that shall be the subject of my next. All is well, and you'll be quite charmed at the simplicity and quietness of Soho engine."

This letter of Mr. Boulton was written on an interesting occasion, to serve as some guide to his partner in estimating the probable amount of his means, with a view to the preparation of a settlement on his second marriage. For it had now become evident that, for the benefit of all parties, and to ensure the success of the new manufacture, it would be necessary for Mr. Watt to live in the immediate neighbourhood of Soho; he thus permanently abandoning his Scottish domicile, and migrating to England *animo remanendi.* Before doing so, however, having found that the burden of domestic affairs and the care of his children interfered seriously with his other pursuits, which had now become vitally important, he, after having remained for some years a widower, married a second time. The lady of his choice on this occasion was Anne, one of the daughters of Mr. Macgregor, a substantial citizen of Glasgow, who, under the instructions of his son-in-law, was the first to practise in this country the useful improvement of employing chlorine in bleaching, which Berthollet, its celebrated inventor, communicated to Mr. Watt. She was the mother of Gregory Watt, as well as of a daughter, both of whom she had the misfortune to lose by their premature death; and she died in 1832, in advanced old age, after witnessing the ripeness of the fame of her husband, of whom, M. Arago has justly said, "her various talent, soundness of judgment, and strength of mind, rendered her a worthy companion."

CHAPTER XVIII.

OFFERS OF EMPLOYMENT IN RUSSIA—PROGRESS AT SOHO—PRIVILEGE GRANTED IN FRANCE—JARY AND PERRIER—M. DE PRONY—VISITS TO CORNWALL—INTRODUCTION OF THE NEW STEAM-ENGINES—PATENT OF 1780 FOR COPYING-MACHINE—MACHINE FOR DRYING LINEN BY STEAM—PATENT OF 1781—"SUN AND PLANET WHEELS"—PATENT OF 1782—EXPANSIVE PRINCIPLE—DOUBLE-ACTING ENGINE—DOUBLE OR COMPOUND ENGINE.

AT this critical turning-point of his life, Mr. Watt had rather a narrow escape from expatriation, and this country from losing all the benefit of his unrivalled career of invention. In 1773 he had received an invitation from his friend Robison to come to Russia, "where he had recommended him to fill some station." But in the spring of 1775 an offer was made to him of employment in Russia, under the Imperial Government, which, at a somewhat earlier period, might probably have met with his thankful acceptance; for the salary promised was 1000*l.* per annum, and the duties required would have suited well his own inclinations and acquirements. The offer of the appointment in question, however, seems to have been ensured by, if it did not originate in, Mr. Boulton "having sounded his praises at the Ambassador's;" and he naturally preferred continuing, with him, those endeavours for a parliamentary prolongation of his first patent, on which their future association was to depend. "Your going to Russia," says Mr. Boulton, "staggers me. The precariousness of your health, the dangers of so long a journey or voyage, and my own deprivation of consolation, render me a little uncomfortable; but I wish to assist and advise you for the best, without regard to self;" and again, "I shall rejoice at every good that befalls you; yet, nevertheless, I find I love myself so well that I should be sorry to have you go to Russia, and I begin to repent sounding your trumpet at the Ambassador's." "Lord, how frightened I was," writes the genial and hearty Darwin, "when I heard a Russian bear had laid hold of you with his great paw, and was dragging you to Russia! Pray don't go if you can help it. Russia is like the den of Cacus; you see the footsteps of many beasts going thither, but of few returning. I hope your fire-engines will keep you here."

The case also of a Captain Perry, (who, after having been engaged by Peter the Great as an engineer, and having served for many years in that country, had been obliged to take refuge in the house of the British Ambassador, and to return to England without receiving his pay,) as well as representations of other similar instances, alarmed him for the consequences which might possibly again attend such despotic predilections; and recommended to his mind the less dazzling, but more secure destiny, of "a crust of bread and liberty." The Imperial family of Russia were then much interested in the various manufactures carried on at Soho, and greatly admired their products. In February, 1776, the Empress stayed for some time at Mr. Boulton's house; "and a charming woman she is," writes her hospitable entertainer.

It is rather a singular circumstance that when, in 1816, his Imperial Highness the Grand Duke Nicholas of Russia, (the late Czar,) applied at the Soho works for permission to view their interior, his application, although supported by a letter from Lord Sidmouth, was rejected. The objection felt, however, was not by any means to the potentate himself or his immediate friends, but to certain persons who followed in his suite, and whom there were good reasons for not initiating into the various processes of the manufacture.

Mr. Watt's labours at Soho soon began to manifest the great advantages which that establishment afforded in respect of materials, workmanship, and business connections. Fortunately, the completion of the reciprocating or condensing engine was not made to wait for that of the more troublesome and uncertain wheel-engine; but was at once proceeded with, under "the master's eye" and care. A cast-iron cylinder, over 18 inches in diameter, an inch thick, and weighing half a ton, but which seemed "tolerably true," "not perfect, but without any very gross error," was procured from Mr. Wilkinson, and the piston, to diminish friction and the consequent wear of metal, girt with a brass hoop two inches broad: and although when first tried, "the engine goes marvellously bad; it made eight strokes per minute; but, upon Joseph's endeavouring to mend it, it stood still;" and that, too, though the piston was helped with all the appliances of "hat," papier maché, grease, black-lead powder, a bottle of oil "to drain through the hat and lubricate the sides," and an iron weight above all to prevent the piston leaving the papier behind in its stroke,—yet, after some imperfections of the valves were remedied, "the engine makes 500 strokes with about two cwt. of coals;" and, in another month or two, with better condensation, it "makes 2000 strokes with one cwt. of coals;" no bad work for such a machine, as yet but in its childhood. "The copper bottom for Bloomfield engine is come," at the same time writes Mr. Boulton, "and Mr. Hurst promises to forward the others directly. The new forging-shop looks very formidable; the roof is nearly put on, and the hearths are both built. The two small 7-inch pumps for our own condenser are this day arrived; but we can't bore them until we have got a block cast for fixing the boring-knives in, which I shall hasten." And, within six months, there comes this order:—"Pray tell Mr. Wilkinson to get a dozen of cylinders cast and bored, from 12 to 50 inches diameter, and as many condensers of suitable sizes; the latter must be sent here, as we will keep them ready fitted up, and then an engine can be turned out of hand in two or three weeks.

I have fixed my mind upon making from twelve to fifteen reciprocating, and fifty rotative engines per annum."

The new engines beginning now to be disseminated over many parts of England, and giving entire satisfaction to all who availed themselves of the invention, began to attract notice on the other side of the Channel. Within a couple of years after the passing of the Act of Parliament of 1775, negotiations were set on foot by MM. Perrier for using Mr. Watt's steam-engines to supply Paris with water; and, in 1778, the King of France, by a decree, granted to Messrs. Boulton and Watt an exclusive privilege to make and sell their engines in that country. This decree, according to the French patent law at that time, could not have the force of a patent till an engine had actually been subjected to the judgment of certain Commissioners appointed by the decree, and had been reported by them to be superior to the common engines. The trial engine, it was agreed, should be erected at the colliery of a M. Jary, near Nantes, in Brittany; M. Jary, who was a very ingenious man, himself undertaking nearly the whole care of the erection.

"The sum of intelligence concerning Perrier," writes Mr. Boulton, "is, that, through interest, he has obtained the King's *arrêt* empowering him to raise water from the Seine to supply Paris, and erecting a company, copy of which I shall send you; that W. Wilkinson went over to solicit order for the pipes, &c.; that Perrier, when he went to Broseley, was resolved to have common engines; that afterwards he was convinced that ours were much superior, and then wanted Wilkinson to make them for him, as he did not see the use of applying to us, [he] being out of our jurisdiction; that W. represented that he would be liable to prosecution, and that he was bound by honour and interest not to do it but through us; that W. thought, as being out of our jurisdiction, we should serve Perrier upon moderate terms, should take out our premium in *actions*, which would be saleable as bearing 6 per cent. interest; that W., if employed for pipes, &c., takes 100 shares at 50*l*. each.

"I answered, that Perrier had not behaved to us with prudent openness or consideration, and had attempted bribing people to betray us at London; that we had friends in France of interest, who had long ago assured us of the protection of the Crown, and that the State would see the propriety of having us to erect our own machines; and that if they did not, we would not serve Perrier so cheap as if they did; that some of our principal secrets were still in our own breasts; that it was more our interest to work at home, without France was secured to us;" &c. * * "Perrier is a smith to trade, and reckoned a man of ingenuity; but his scheme is undigested, and he is ignorant even of the proper method of conducting the water. The Lieutenant of Police is the ultimate judge of disputes in Perrier's scheme. Rather than fail, suppose we were to erect one or two engines for Perrier upon easy terms, provided he and his interest concurred in securing our property in France."

Early in 1779, Perrier visited Soho, "bargained on very moderate terms" for engines, and drawings for one were sent to Jary by Mr. Watt, to be executed, it would appear, in France. Finding, in May, 1780, that the MM. Perrier were to erect three fire-engines, "whereof one according to our plan, and the two others with 'changements qu'il avoit imaginé,' if we mean to keep this our kingdom of France in proper subjection," wrote Mr. Watt, "it will be necessary that one of ourselves go over there soon."

How far MM. Perrier showed off to advantage the engine of English design and French construction, appears from the report of M. De Luc, "who was present at Paris when Perrier called the Royal Academy to view the engine set out, when, lo! it went *two* long strokes per minute; which he said was owing to the want of the steam-case, which in haste he had omitted. This being afterwards added, the engine wrought at the rate of four strokes per minute, and he (De Luc) never saw it go any faster."*

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* Mr. Watt to Mr. Boulton, 29 October, 1782.

This was rather a contrast to the rate at which the Soho engines moved in their own country; and perhaps M. Perrier prevailed on the two others, "with variations which he had imagined," to mind their business with more alacrity. But when Mr. Watt and Mr. Boulton visited Paris, "We have also vindicated," writes Mr. Watt,* "the honour we were robbed of by Mr. Perrier's assuming the merit of my invention; he said our coming was *un coup de soufflet diabolique pour lui.* He has succeeded, however, in having erected a most magnificent and commodious manufactory for steam-engines, where he executes all the parts most exceedingly well. He is a man of abilities, and would be very estimable if he were a little more just, (or more honest.)" And, in 1790, he again writes,† "I have a letter from Mr. Levêque of July 4th. He has seen Perrier's engine, which he does not like; says Mr. De Betancourt instructed him how to make double engines, and has sent a model of them to Spain, as he does of everything he sees; and has written a memoir upon the effects of steam, which will be published in Prony's 'Hydraulogie.' We must be more and more careful in respect to foreigners." M. De Prony (who usually spells the name of Watt either *Wats* or *Wast*) has an article in his 'Nouvelle Architecture Hydraulique,' (No. 1345, tome i., published in 1790,)—"Comment M. le Chevelier De Betancourt *a deviné le principe* d'une machine à feu postérieurement construite par MM. *Wats* et *Bolton*:"—on perusing which, it turns out that the engine alluded to was the double-engine; that the method M. De Betancourt took to "divine the principle," was to visit and inspect the engine itself at work at Soho; to observe the piston impelled both upwards and downwards by an equal force of steam; and then, having made a model, to get MM. Perrier to make an engine on the same construction as that which he had thus visited, inspected, and observed at work.

But it is satisfactory to be able to add, that, on a personal acquaintance with M. De Prony, Mr. Watt found that he was a very estimable man; and that in any mistakes he had made as to the steam-engine, he had proceeded on erroneous information, and was anxious to correct them. "I acquit him," writes Mr. W., in 1808, "of all blame or envious intention; he was merely the chronicler of what was related to him; and with such relators as Perrier and Betancourt at his ear, what better could be expected? He knew nothing of me or my works but what they pleased to relate. He is himself a most ingenious, modest, and candid man, and regrets much his having published what he has done; and he offered to insert in his next publication whatever I pleased to communicate on the subject."[*] In 1816 Mr. W. signed M. De Prony's certificate for the Royal Society; and, in returning it to Mr. Rennie, observed that he was glad to have had an opportunity of giving this testimony of his esteem for him.[†]

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* To Dr. Roebuck, 3 February, 1787.

† To Mr. Boulton, 23 July, 1790.

For many years after 1775, Mr. Watt resided chiefly in Birmingham, to be near the great manufacturing establishment to which his attention was now energetically devoted; but he was sometimes compelled to be absent, for long periods, in the mining districts of Cornwall,—a poor exchange, in his opinion, for the intellectual pleasures and hospitable sociality of the neighbourhood of Soho. His employments, during those intervals of forced absence, were, to a great extent, neither easy nor agreeable. He had, in the first place, to push his great invention into notice and use; in doing which, he had to contend not only with such obstacles as nature presented, in the dark abysses of desperately-flooded mines, but also with the deeply-rooted prejudices of a rude and obstinate class of men, generally as incredulous of the powers of the new machine, as they were ignorant of the causes of the imperfections of the old ones. How little, too, the real merits of machinery were appreciated by those among whom he had to labour, appears from an amusing description he has given* of one of the first engines which he erected in Cornwall. "At present," he says, "the velocity, violence, magnitude, and horrible noise of the engine give universal satisfaction to all beholders, believers or not. I have once or twice trimmed the engine to end its stroke gently, and make less noise; but Mr. ——— cannot sleep unless it seem quite furious, so I have left it to the engine-man. And, by-the-bye, the noise serves to convey great ideas of the power to the ignorant, who seem to be no more taken with modest merit in an engine than in a man." Naturally disinclined to solicitation, and averse to the coarse tumult of commercial business when conducted with inferior and illiberal minds, he was expected to obtain orders and extend connections; as well as to take charge, (as he did with much greater readiness,) of the erection of the new engines, and of making experiments on all sorts of old ones. In public discussions at the meetings of mining adventurers, his arguments, founded on reason and science, too often met with jarring opposition,—sometimes even with ignorant contempt;—in private he had "constant bad headaches," and his "usual tendency towards desponding views." As business increased, so did his troubles: "excessive difficulty in finding intelligent managing clerks;"—"continued anxiety," (and frequent failure,) "to get the various parts of the metal-work executed exactly according to his own drawings," which, it is needless to say, were made with laborious accuracy and clearness; so that, "almost distracted with multiplicity of orders," he sometimes fancied, he said, that he "must be cut in pieces, and a portion sent to every tribe in Israel!" Then, as soon as the real value of the new engines began to be at all understood,—as soon as that water which was reckoned the "heaviest" in the whole county, and which the sapient among the miners had, in the profundity of their wisdom, declared would never be "forked," not only was "forked," but showed, by the manner in which that process was accomplished, that the new engine "might fork anything,"—to all his previous labours was added that hateful one of having to observe and restrain the piracies which forthwith began to be practised, secretly at first, but soon with greater frequency and daring.

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[*] Mr. Watt to Mr. James Watt, jun., 10th November, 1808.

[†] To Mr. Rennie, 5th December, 1816.

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* In a letter to Mr. Boulton from Truro, without date.

The bare and miserable aspect of the country in which his head-quarters were at such times most commonly fixed, increased the gloom of the months he was compelled to spend there. Cornish mines are far from resembling the fabled scenery of the golden age; and the following description of one, though drawn with a lively pencil, and inserted in a work of fiction, is, we believe, true to Nature:—"It was an ugly, uninviting place to look at, with but few visible signs of wealth. The earth, which had been burrowed out by those human rabbits in their search after tin, lay around in huge ungainly heaps; the overground buildings of the establishments consisted of a few ill-arranged sheds, already apparently in a state of decadence; dirt and slush, and pools of water confined by muddy dams, abounded on every side; muddy men, with muddy carts and muddy horses, slowly crawled hither and thither, apparently with no object, and evidently indifferent as to whom they might overset in their course. The inferior men seemed to show no respect to those above them, and the superiors to exercise no authority over those below them. There was a sullen equality among them all. On the ground around was no vegetation; nothing green met the eye; some few stunted bushes appeared here and there, nearly smothered by heaped-up mud, but they had about them none of the attractiveness of foliage. The whole scene, though consisting of earth alone, was unearthly; and looked as though the devil had walked over the place with hot hoofs, and then raked it with a huge rake."* The "dismal weather did not tend to raise his spirits;" those wilds, he says, might be defined "a tract of hills without dales," where the roads went "straight up the hills without flinching," and where,—(the force of savage misery could no further go!)—"*the engine-men actually eat the grease for the engine!*" Some of his letters indeed remind one, although, of course, in all the sobriety of engineering prose, of the strains in which Ovid bewailed his exile to the remote and savage Pontus;—"peace of mind, and delivery from Cornwall, is my prayer," was his desponding message to Soho in 1782. But, as the Muse did not cease, amid the horrors of barbarian skies, to cheer with her smiles the lonely hours of the expatriated Roman poet, so the spirit of Invention did not forsake her favourite son in his Cornish solitude; and even his '*Tristia*' give token of her inspiration.

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* 'The Three Clerks,' vol. i., p. 199.

The copper companies becoming bankrupt, or, at least, insolvent, in rapid succession, and many of the mines being already unworkable from the increase of water, while the low price of copper would not admit of the removal of that obstacle by the old and expensive means, were all circumstances which, however unpropitious at first sight, really proved advantageous to the cause of the new steam-engine, by compelling the adoption of every principle by which economy of fuel and labour could be attained.

Nevertheless, the result to Boulton and Watt in the way of emolument was for several years questionable enough; for in 1780, "it appears," says Mr. Watt,* "by our books, that Cornwall has hitherto eat up all the profits we have drawn from it, and all we have got by other places, and a good sum of our own money to the bargain." Even in 1783 he writes,—"we have altered all the engines in Cornwall but one, and many in other parts of England; but do not acquire riches so fast as might be imagined; the expenses of carrying on our business are necessarily very great, and have hitherto consumed almost all our profits; but we hope to do better by continuing our attention and exertions, and by multiplying the number of our works."† Yet the state of matters from which the new steam-engine redeemed the failing mines, is thus, at the same period, described by him:—"Chace water Company sunk 50,000*l.* and upwards in setting that mine to work; and whether they have recovered it all yet seems uncertain, although the mine has been tolerably prosperous. Wheal Virgin & Co. lost 28,000*l.* in ten months' unprosperous working. Poldice has sunk a very great sum, and is not now gaining nor saving. It has cost 35,000*l.* to fit up and drain Wheal Virgin in this working, and it costs above 10,000*l.* a-year to draw the water, after all that can be done for them. Pool adventurers have sunk near 14,000*l.*, and have no great prospect of recovering any part of it. Roskeere has been long languishing, and does not now pay costs. At Dolcoath Mine it is said they use 500*l.* of timber per month, and a new kibble rope of above a ton weight is worn out in a fortnight. It takes fully 15 minutes to draw a kibble of ore there, which weighs only about 3 cwt. On the average, above $\frac{2}{3}$ of the stuff drawn is barren stones. It cost three years' work, and, I believe, as many thousand pounds, to sink a new shaft in that mine:—every fathom of an engine-shaft that is sunk under the engine costs from 50*l.* to 100*l.* United Mines have been at death's door, and are still in a tottering state. Wheal Union adventurers, after working near three years, were glad to sit down with a loss of 7000*l.* or 8000*l.* If we had not furnished them with more effectual means of drawing the water, I believe almost all the deep mines had been abandoned before now."

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* To Mr. Boulton, 31 October, 1780.

† Mr. Watt to Mr. Macdowal, 3 January, 1783.

With Mr. Watt, the whole of the period of which we are now speaking, whether passed by him at Birmingham, in Cornwall, or elsewhere, was one of the most continuous, versatile and active exertion, and the most profusely fertile in mechanical invention, of the whole of his life. This may be said to have been the case more especially as regards the first ten years of the time in question, viz., from 1775 to 1785, during which he secured, by five several patents, the invention of the machine for copying letters and drawings, together with those almost innumerable improvements on the steam-engine, of infinite ingenuity and value, which he had made subsequent to that of the separate condenser; besides originating other contrivances, which, although not included by him in patents, might have made both the fortune and the reputation of many a minor adventurer in that line.

Taking his patents in their chronological order, the first, (subsequent to that of 1769,) is that "For a new method of copying letters and other writings expeditiously,"—which passed the Great Seal on the 14th of February, 1780, the specification being enrolled on the 31st of May following. The first idea of this invention is believed to have originated in Mr. Watt's mind from his perception of the advantages of a scheme proposed by Dr. Darwin, of a sort of duplex pen which he called a bigrapher, but which we are not aware that there is any great reason for supposing to have been very successfully employed in practice. His bigrapher perhaps resembled that notable "instrument for writing many copies of the same thing at once," contrived and patented by Sir William Petty in 1648, which, "when it came to be tried, was found to take considerably more than twice the time to produce its two copies than the common pen took to produce one." *

To Dr. Darwin accordingly was sent one of the early intimations of the completion of the modern copying-machine:—"I have fallen on a way of copying writing chemically, which beats your bigrapher hollow. I can copy a whole-sheet letter in five minutes. I send a copy of the other page enclosed for your conviction, and I tell you further that I can do still better than that copy." † To Mr. Boulton, ‡ "I send you enclosed some of Mr. Nobody's draughts, with authentic copies of them. * * The copy will continue to grow blacker as other writing does, and I fancy you will find the originals rather blacker than they were before copying, and, as far as I can judge, not in the least defaced." And in December, 1779, he writes to Dr. Black, "In relation to

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* Romance of the Peerage, vol. iv. p. 258-9.

† The letter is without further date than Birmingham, 1779.

‡ 28 June, 1779.

the copying scheme, the state of it at present is as follows:—I have given in a petition for a patent, and it is now in train; but as my occupations and health cannot permit me to follow that business myself, I have taken in two partners—Mr. Boulton, who is to be at the expense of the patent, and Mr. Keir, who is to manage the business.

"In brief, the first idea was the forcing the ink through thin paper, so as to appear on the other side; the second, the improving the colour by wetting the paper with an astringent; the third, the depriving astringents of their colour, without depriving them of their effects as astringents; fourthly, managing the operation so as to prevent the original being defaced, or forced through to the other side; but the greatest part resides in the mechanical manœuvre. All this to yourself *only* at present."

Specimens of the result of the process its inventor amused himself by supplying to others of his correspondents, as having been mysteriously done, like the magical typography of Fust, "*Non Atramento aut Plumali Cannâ, sed Arte quâdam Novâ.*"

The difficulty of finding materials suitable in all respects to the new process, led him to make a great number of experiments, especially in regard to the ink which was fittest to be used in order to insure clearness and durability in the copy, without injury to the original; and, finding that the time consumed by that long series of trials interfered inconveniently with his other not less urgent occupations, he assumed as partners in the copying-press business, as mentioned above, both Mr. Boulton, (who was at the expense of the patent,) and their mutual friend Mr. Keir, who was possessed of an active and well-informed mind, and whom his own inclinations had led to the study of chemistry and the application of it to the arts. That the manufacture of the copying-presses prospered under their joint management, is attested by the number of public, mercantile, and other offices, as well as of private individuals, that were supplied with those useful implements; which have, indeed, been ever since considered in this country as indispensable to the rapid, easy, and safe transaction of business in every extensive concern.

To the inventor this ingenious contrivance brought its own reward:—for he says in writing to one of his correspondents, (to Mr. H. B. Way, 27th March, 1809,)—"It is gratifying that you find the copying-machine useful to you. It has been so much so to me, for the last twenty-six years, that it has been worth all the trouble I had with it, had it been attended with no other profit." Early in 1781, his friend Dr. Patrick Wilson wrote to him on this subject, giving a very useful hint, which was carried out in practice by the contrivance of *damping-boxes* made of wood, lined with tin-foil or sheet-lead, with a lid fitting close to the interior of the sides, so as to admit of either a small or a large quantity of copying-paper being damped at one time.

"My method is to prepare in daylight, and when at leisure, by the wetting book, as much paper as will serve for a month, which I preserve in that state of moisture, by keeping the leaves betwixt boards of wainscot with TIN-FOIL next the paper. I have three sets of these boards, for the half-folio, quarto, and next size of paper; but the tin-foil is an inch beyond the leaves all round, so as to fold down; the more effectually to prevent the moisture from escaping. The uppermost board is loaded with sheet-lead, and the undermost has a handle, to draw them more conveniently from the under shelf of the copying-table, where they always lie when not in use. Yesterday I tried some sheets preserved moist in this way for 23 days, and the copy was extremely distinct and equal, owing to the moisture being more uniformly diffused than in the common way. * * But there may be still more commodious ways found of applying this principle in practice."

It is hardly necessary that we should here describe the simple process, so well understood at the present day, of exposing the letter to be copied, interleaved with damp unsized copying-paper and oiled paper, or pasteboard, to pressure for a few seconds between the rollers of a rolling-press; or, in fact, to any adequate and equable pressure, not too powerful; so that the ink may be duly impressed on the copy without being also forced through the letter-paper so as to injure the appearance of the letter. The machines manufactured for this purpose by James Watt and Co. (under which firm the Soho copying business was conducted,) were, with hardly an exception, made with rollers; at first of lignum-vitæ, but afterwards of iron; the wood having been found, from the alternations of damp and dryness, to have a tendency to crack or split.

It was, however, also proposed by Mr. Watt in his specification, to use, instead of a rolling-press, *a screw-press*, "or any other pressure sufficient" for the purpose; and in the screw-press delineated in the drawing which accompanied it,* will at once be recognized what, under a variety of forms and unimportant modifications, is in fact the common modern copying-press. But it will still, we think, be found, that the rollers, when properly managed, do their work more effectually than the screw; and that Mr. Watt's preference of them in his own practice was therefore not unfounded.

On the immense utility of the contrivance, it is quite unnecessary to enlarge; but we may observe that for copying drawings,—a purpose for which, though expressly specified, it has, we believe, been in general but seldom used,—its merits are quite as great as for that to which it is more commonly applied. The drawing being made, as writings ought to be, with ink sufficiently mucilaginous for the purpose, the copy can be taken either on the common transparent copying-paper, or on unsized drawing-paper;—in the latter case, the copy being reversed as the impression of an engraved plate, care must be taken that any letters of reference, or descriptive titles, are not added to either the original or the copy until after the latter has been thrown off. For this purpose, pressure between rollers is decidedly preferable to that obtained by the screw. In the establishment at Soho, it has been the practice, by the aid of this excellent invention of its great founder, to retain copies of the drawings of all the engines sent out from that manufactory.

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* 'Mechanical Inventions of James Watt,' vol. iii. plate II. fig. 3.

To this short notice of the copying-machine we have only to add, that the late Mr. James Watt, jun., having, in the course of his extensive business correspondence and frequent absence from home, felt the inconvenience of separation from so useful an assistant in the labours of the bureau as the machine thus invented by his father, contrived an extremely useful portable form of it. In this, small brass rollers are used instead of the larger and more ponderous iron ones; and the whole apparatus, with a full supply of stationery, &c., is commodiously arranged in a travelling desk of mahogany, little more than a foot square, and not above six inches high. The exact dimensions of one now before us are $13\frac{1}{2} + 11\frac{1}{2}$ inches; height 5 inches.

Of the same date as the copying-machine was Mr. Watt's invention of a machine for drying linen and muslin by steam; a drawing of which, with explanations, he sent to Mr. Macgregor, his father-in-law, on the 4th of February, 1781. "It consists," he then wrote, "of three cylinders of copper, which the cloth must turn over and under while they are filled with steam. I have also added to it a drawing of the method by which the water condensed may be returned to the boiler. The joinings of the parts may be made good with soft solder. * * I presume you understand the cloth is to be alternately wound off and on the two wooden rollers, by which means it will pass over the three cylinders in succession." Mr. Macgregor had it executed, under the superintendence of Dr. Irvine and Mr. Gilbert Hamilton, by John Gardiner, an ingenious artisan whom Mr. Watt had often employed as one of his journeymen, in earlier years, when resident in Glasgow. "This," he wrote in 1814 to Sir David Brewster, "I apprehend to be the original from which such machines were made, and which, I believe, is claimed by somebody else. If you think it worth publication, I shall cause a copy [to be made] and send it you—it possesses some merit." The machine is described in Brewster's Edinburgh Encyclopædia, vol. xviii. p. 384, and the drawing of it is engraved on plate DXI. of that work, figs. 7, 8, 9, and 10.

On the 25th of October, 1781, Mr. Watt took out his third patent, (the second of the steam-engine series,) of which the specification was enrolled on the 23rd of February, 1782, "for certain new methods of applying the vibrating or reciprocating motion of steam or fire engines, to produce a continued rotative motion round an axis or centre, and thereby to give motion to the wheels of mills or other machines." The application for this patent was rendered necessary by the difficulties that had been experienced in working the steam-wheels or rotatory engines, such as that described in the specification of 1769; and by Mr. Watt having been unfairly anticipated by Wasborough, &c., in the application of the crank. "I know the contrivance," he writes to Mr. Boulton in April, 1781, "is my own, and has been stolen from me by the most infamous means, and, to add to the provocation, a patent surreptitiously obtained for it. * * I know from experiment that the other contrivance which you saw me try, performs at least as well, and has, in fact, many advantages over the crank." And again, in the same month, "if the King should think Matt. Wasborough a better engineer than me, I should scorn to undeceive him; I should leave that to Matthew. The conviction would be the stronger, as the evidence would be undeniable!"

In the Specification, no fewer than five different methods are enumerated, by any one of which the proposed end might be attained without the intervention of a crank; all of them admitting, as therein mentioned, of many varieties. The fifth is that commonly known as the "Sun and Planet wheels."

To all of the five methods which it describes, where heavy wheels or swift motions are not otherwise necessary for the uses to which the methods are to be applied, the specification recommends that a fly-wheel should be applied to equalize the motion. But, as Mr. Watt has observed, his application of the double engine, (described in the specification of 1782,) to those rotative machines, rendered unnecessary the counterweight, and produced a more regular motion; "so that," he says, "in most of our great manufactories these engines now supply the place of water, wind, and horse mills; and, instead of carrying the work to the power, the prime agent is placed wherever it is most convenient to the manufacturer."—(Notes to Robison, p. 135.)

"From the time of the first invention of the improved engines," (Mr. Watt writes to his son, 10th November, 1808,) "I was desirous of applying them to giving motion to mills in some better way than by raising water to turn a water-wheel. One method I described in the patent," (i. e., of 1769): "the reason why that method was not pursued, it is now unnecessary to enter upon. Of another method I made a model soon after, which still exists in an unfinished state, and several more have since been devised by myself and others. All these were self-acting rotative engines, not derived from the rectilinear motion of a piston in a cylinder. They have their respective merits; but instead of being more simple in their construction, they are more complex than those derived from reciprocating motions, and more difficult in execution.

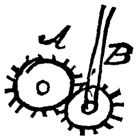
"The first I know of, of the latter kind, was one I saw at Hartley Colliery about 1768, which consisted of a toothed sector on the end of the working-beam, working into a trundle, which, by means of two pinions with ratchet wheels, produced a rotative motion in the same direction, by both the ascending and descending stroke of the arch; and by shifting the ratchets the motion would be reversed at pleasure, when one of the ratchets was arrived at the bottom. It was employed to draw coals out of a pit, had no fly-wheel, and went sluggishly and irregularly; the name of the inventor I have long since forgotten. One Stewart had a patent for an engine which produced a rotative motion, by a chain going round a pulley and round two barrels furnished with ratchet wheels, with a weight suspended to the free end of the chain, which served to continue the motion during the return of the engine. I have never seen this, but believe there was no fly. Whether this was the same as Mr. Clarke's or not, I know not. The next I know of is Matthew Wasborough's, which was virtually the same as that I saw at Hartley, but Matthew *had added a fly-wheel*, which, as far as I know, was the first time that it had been employed for that purpose. I at present recollect nothing of Fitzgerald's rotative engine, but think it was something of the ratchet kind.

"The true inventor of the crank rotative motion was the man, (who unfortunately has not been deified,) that first contrived the common foot-lathe." (In another letter to his son about the same date, Mr. Watt says, "The real inventor of the rotative motion was the man, be he Chinese, Indian, Arabian, Greek, or Goth, who first made a common foot-lathe. The applying it to the engine was merely taking a knife to cut cheese which had been made to cut bread.") "My share in the application I remember perfectly to have been as follows:—One of Matthew Wasborough's rotative engines was erected at Birmingham, for a rolling-mill, and was much talked of. This set me again to think upon the subject, and brought to my remembrance my former meditations upon the crank, the date of which I cannot ascertain." It appears to have been at all events prior to 1771, for early in that year Mr. Watt writes:—"I have at times had my thoughts a good deal upon the subject, but have not hit upon anything decisive; only in general it appears to me that a crank of a sufficient sweep will be by much the sweetest motion, and perhaps not the dearest, if its durability be considered." "I was, however, desirous to render the motion continued and equable without a fly-wheel, the regulating power of which I did not then fully appreciate, nor the advantage to be derived to the engine from the crank causing the motion of the engine to be slow at the beginning and end of the stroke; which, however, a few experiments with other contrivances soon made me sensible of. I then resolved to adopt the crank; and, to equalize the power, I proposed to adopt two cylinders acting upon two cranks fixed upon the same axis at an angle of 120 from each other, and to place a weight on the circumference of the fly-wheel at an angle of 120 from each of the cranks; which weight was to be so adjusted as to act when neither of the cranks could do so, and, consequently, to render the power in itself nearly equable. Or to place the two cranks at right angles to each other, and to load the outer end of the working-beams of the two cylinders with weights equal to half the power of the respective cylinders, which might act during the time of the ascents of the respective pistons.

"Of this I caused a model to be made, which performed to satisfaction. But, being then very much engaged with other business, I neglected to take a patent immediately, and, having employed a blackguard of the name of Cartwright, (who was afterwards hanged,) about this model, he, when in company with some of the same sort who worked at Wasborough's mill, and were complaining of its irregularities and frequent disasters, told them he could put them in a way to make a rotative motion which would not go out of order nor stun them with its noise, and accordingly explained to them what he had seen me do. Soon after which, John Steed, who was engineer at Wasborough's mill, took a patent for a rotative motion with a crank, and applied it to their engine. Suspicions arising of Cartwright's treachery, he was strictly questioned, and confessed his part in the transaction when too late to be of service to us. I had afterwards a conversation with Steed upon the subject, who said that he had made the invention before he was informed of Cartwright's communication, and had taken his ideas from the common foot-lathe; and that Cartwright's information had no other effect than to accelerate his taking out the patent. How this was I know not; it is certainly possible that Steed might have invented it; but what I have related is the fact as far as concerns my invention.

"Finding the door thus closed upon us, and circumstances making us unwilling to go to law with the patentees, which could only have had the effect of throwing the invention open to the public if we had succeeded, we judged it better to let it remain with them,—who did not seem capable of doing us much harm,—than to let it get into the hands of men more ingenious, being sensible at the same time that their rotative motion could not do much good, without it were attached to our engines. We therefore thought it better to take a patent for several contrivances on the same principle, which the former patentees never thought proper to call in question. The revolving wheels was the one which we principally adopted; but the advantages of the crank in point of simplicity have made it now to be generally used, and the other to be laid aside, perhaps for ever."

With regard to the fifth method specified, that, namely, of the "sun and planet wheels," which perhaps was the most ingenious and elegant, as well as the most practically useful, of all the five, it is to be observed that, although its invention dated from an *earlier* period in Mr. Watt's life, it seems to have been revived in the interval between taking out the patent and giving in the specification. Living at that time in Cornwall, Mr. Watt went to Penryn on the 25th of July, 1781, and made the affidavit to accompany his petition for the patent; and on the 3rd of January, 1782, he writes to Mr. Boulton:—"I wrote to you on the 31st, since which I have tried a model of one of my old plans of rotative engines, revived and executed by Mr. M[urdock], and which merits being included in the specification as a fifth method; for which purpose I shall send a drawing and description next post. It has the singular property of going twice round for each stroke of the engine, and may be made to go oftener round, if required, without additional machinery. The wheel A is fixed at the end of an axis which carries a fly; the wheel B is fixed fast to the connecting-rod from the working-beam, and cannot turn on its axis, and is confined by some means, so as always to keep in contact with the wheel A; consequently by the action of the engine it goes round it and causes it to revolve on its axis; and if the wheels are equal in the number of their teeth, A will make two revolutions while B goes once round it." Two days later,* "I send you the drawings of the 5th



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* To Mr. Boulton, 5 January, 1782.

method, and thought to have sent you the description complete, but was late last night before I finished so far, and to-day have a headache, therefore only send you a rough draft of part. The drawing is made to ½-inch scale for 6-feet stroke, but must be reduced to the ¼-inch. * * This 5th method makes an exceeding good motion, and may in many ways be very useful, from its peculiar properties." And, two days later still,—"I wrote to you on Saturday, with drawings of the 5th method of rotatives, and enclosed I send the complete specification of that method."

The drawings for this specification were made, in duplicate, by Mr. Watt's own hand; one of them "on stamped parchment for want of plain," and the other, "in an elegant manner upon vellum, being the neatest drawing," he says, "I ever made: and [I] have improved the construction of several of the machines, and represented their stands and several other parts necessary. The double-toothed wheels," [the sun and planet motion,] "admit of several different applications, one of which admits the rotative wheel to be in the middle of an axis, and that was the original one." He says in another letter, before the specification was given in, "I have thought on some other methods by which rotative motions may be made, but they are inferior to those specified, and I feared the specification would have grown four yards long."*

While preparing the specification of the patent of 1781, for the five methods of producing a continuous rotative motion round an axis, from the vibrating or reciprocating motion of steam-engines, so as to give movement to mill-work, Mr. Watt was already arranging the contents of another patent of quite as great importance. The title of the new patent, which passed the Great Seal on the 12th of March, 1782, was quite a general one; being "for certain new improvements upon steam or fire-engines, for raising water, and other mechanical purposes, and certain new pieces of mechanism applicable to the same." But in the specification, which was enrolled on the 4th of July, 1782, are comprehended the following "new improvements:"—

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* See the specification printed in vol. iii. of the 'Mechanical Inventions of James Watt,' 1854, pp. 36 to 54; and the relative drawings engraved on Plates III. IV. V. VI. and VII. of the same volume.

1. The use of steam on the expansive principle; together with various methods or contrivances, (six in number, some of them comprising various modifications,) for equalising the expansive power.

2. The double-acting engine; in which steam is admitted to press the piston upwards as well as downwards; the piston being also aided in its ascent as well as in its descent by a vacuum produced by condensation on the other side.

3. The double-engine; consisting of two engines, primary and secondary, of which the steam-vessels and condensers communicate by pipes and valves, so that they can be worked either independently or in concert; and make their strokes either alternately or both together, as may be required.

4. The employment of a toothed rack and sector, instead of chains, for guiding the piston-rod.

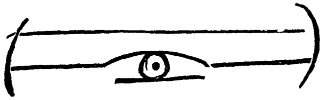
5. A rotative engine, or steam-wheel.

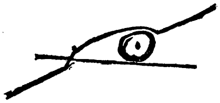
1. It appears from one of Mr. Watt's letters, (to Mr. Boulton, 19th November, 1781,) that he had first thought of the expansive engine in 1767; and had also explained it to Mr. Smeaton, at Soho, some years previous to 1781. Its principle is a curious one, and appears at first paradoxical; for, in fact, by cutting off the supply of steam at a certain point before the steam-vessel or cylinder is full, the same effect is produced as if the steam-vessel had been entirely filled with steam: the expansion, or elastic force which the steam exerts, doing the same work that in the other case would have been done by a greater quantity of steam, and, therefore, a further expenditure of fuel. The proportion of steam specified by Mr. Watt as being most convenient for admission, in common use, was one-fourth of the contents of the steam-vessel; producing an effect equal to more than one-half the effect that would have been produced had steam been admitted to enter freely into the cylinder during the whole length of the stroke of the

piston. But he adds that any other proportion would produce similar [proportional] effects, and that in practice he did vary the proportions accordingly.

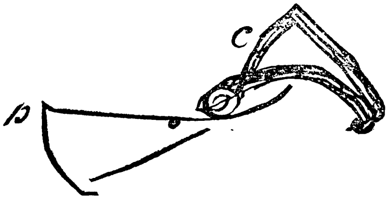
But the powers thus exerted by the steam being unequal at different periods of the stroke, while the resistance to be overcome, or work to be done, by the engine, was supposed to be equal throughout the whole length of each stroke, it was necessary to equalise the power of the engine; for doing which six different methods are specified. And, as of two of them, (viz., the first and third,) there are two varieties, and of another, (viz., the fifth,) there are four varieties, we have here no fewer than eleven varieties of such equalising machinery described, for particulars of all of which reference must be made to the specification, and relative plates.

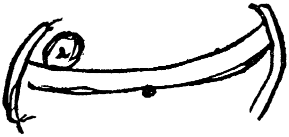
To exhibit some of those "equalisers" in their embryo stage, we may give from Mr. Watt's correspondence the following extracts, written between the date of his making the affidavit to accompany the petition, and the enrolment of the specification. The extracts are all from letters written to Mr. Boulton, from Cosgarne, (in Cornwall,) and are dated respectively the 9th, 11th, and 14th of February, 1782:—"I have nothing new to advise you of, except a new method of an equalising beam, by causing the gudgeon to change its place, thus—

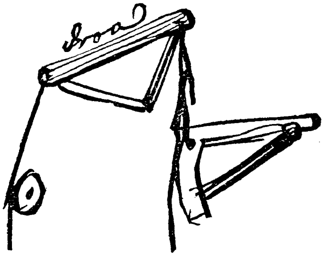


The working-beam is made hollow on the under-side, and rests upon a roller which has an axis through it, and this axis has a wheel fixed upon each end of it, unconnected with the roller, but connected together by means of the axis. At beginning of the stroke the roller and beam stand thus— 

but as the engine-end descends, the curve forces the roller to travel towards the pump-end, and *vice versâ*. N.B. The wheels, and not the roller, rest upon the fulcrum or support. I have also made sketches of some equalising beams, which perform by means of a roller acting upon a curve in the nature of the working gear; the engine pulls by the arch C, and the pump is hung to the arch P; the roller travels about the length of the stroke, and the curve permits a perfect equalisation;”—“I have filled one whole sheet, royal, with equalisers, and shall probably fill another before I am done;”—“I remark what you said in your last about equalisers, and had thought of the same; below are two new ones. But the flyer is the best of all, and will prove the true equaliser, and will have much less friction than any other. It may, however, be combined with some of the most simple ones; and the weight raised by the back-stroke may be placed so far above the centre as in some measure to equalise itself.”







2. The double-acting engine, as appears from the letter to Mr. Boulton already referred to, where Mr. Watt calls it the “double cylinder,” was also imagined by him about 1767. A large

drawing of it on parchment, now in our possession, made from a sketch by Mr. Watt, was laid before the Committee of the House of Commons when Mr. Watt was soliciting the Act of Parliament for the extension of the patent, in 1774–5. The reason of it not having been sooner secured by a patent, was the difficulty which its inventor "had encountered in teaching others the construction and use of the single engine, and in overcoming prejudices:"—and the patent of 1782 was, even then, taken out only in consequence of Mr. Watt "finding himself beset with an host of plagiaries and pirates." In the same time, and with almost the same machinery, the engine on this new principle was enabled to do double the work of the single engine, independent of the additional saving resulting from the use of the expansive principles already explained, by which it could be used as a double-acting expansive engine; in which case the fourth, fifth, and sixth of the contrivances for equalising the powers of the steam are specified as being peculiarly applicable.

One of the earliest double-acting engines completed for sale was one of those for the Albion Mills, erected in 1786, at the south-east corner of Blackfriars Bridge. "The mention of the Albion Mills," says Mr. Watt, "induces me to say a few words respecting an establishment so unjustly calumniated in its day, and the premature destruction of which, by fire, in 1791, was, not improbably, imputed to design. So far from being, as misrepresented, a monopoly injurious to the public, it was the means of considerably reducing the price of flour while it continued at work.

"It consisted of two engines, each of fifty horses' power, and twenty pairs of millstones, of which twelve or more pairs, with the requisite machinery for dressing the flour and for other purposes, were generally kept at work. In place of wooden wheels, always subject to frequent derangement, wheels of cast-iron, with the teeth truly formed and finished, and properly proportioned to the work, were here employed; and other machinery, which used to be made of wood, was made of cast-iron, in improved forms;

and I believe the work executed here may be said to [have] form[ed] the commencement of that system of mill-work which has proved so useful to this country. In the construction of that mill-work and machinery, Boulton and Watt derived most valuable assistance from that able mechanician and engineer, Mr. John Rennie, then just entering into business, who assisted in planning them, and under whose direction they were executed. The engines and mill-work were contained in a commodious and elegant building, designed and executed under the direction of the late Mr. Samuel Wyatt, architect."*

We may add, that Mr. Peter Ewart was then Rennie's apprentice, was sent for from Scotland expressly to assist in the erection of those mills, and was employed for four years upon them as a millwright; when his great mechanical talents and industry sufficiently recommended him to his future employers, patrons, and friends, Messrs. Boulton and Watt.†

We have here spoken of the "double-acting" engine, (a name sometimes applied to it on its first introduction,) to distinguish it from the next of the new improvements included in the specification of 1782, viz.:—

3. The double, or *compound* engine; the nature and advantages of which are thus shortly described by Mr. Watt:—"A new compound engine, or method of connecting together the cylinders and condensers of two or more distinct engines, so as to make the steam which has been employed to press on the piston of the first, act expansively upon the piston of the second, &c., and thus derive an additional power to act either alternately or conjointly with that of the first cylinder."‡

4. Toothed rack and sector, instead of chains, for guiding the piston-rod. In consequence of Mr. Watt's beautiful invention of the Parallel Motion, made at no distant date from that of this

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* Notes on Robison, p. 137.

† See the 'Address of the President,' James Walker, Esq., 'of the Institution of Civil Engineers, to the Annual General Meeting, January 17, 1843.'

‡ Notes on Robison, p. 150.

specification, the rack and sector may be looked on as having been only a temporary expedient to avoid the inconveniences which had been found to result from the old system of chains connecting the piston-rod with the beam.

5. Rotative engine, or steam-wheel. For the reason already mentioned when treating of the patent of 1781, viz.: that "self-acting rotative engines, not derived from the rectilinear motion of a piston in a cylinder, instead of being more simple in their construction, are more complex than those derived from reciprocating motions, and more difficult in execution," it seems unnecessary to enlarge on this article, which is fully described in the specification.*

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* See the specification of this third steam-engine patent, printed in vol. iii. of the 'Mechanical Inventions of James Watt,' 1854, pp. 55 to 87; and the relative drawings, engraved in the same volume, Plates VIII., IX., X., XI., XII., XIII., XIV., XV., XVI., XVII., XVIII., and XIX.

CHAPTER XIX.

STEAM TILT-HAMMER—PATENT OF 1784—PARALLEL MOTION—LOCOMOTIVE STEAM-CARRIAGES — COUNTER — THROTTLE-VALVE—GOVERNOR—STEAM BAROMETER OR FLOAT—STEAM-GAUGE—INDICATOR—MOST INVENTIVE PERIOD OF MR. WATT'S LIFE—DEATH OF HIS FATHER—PATENT OF 1785—CONSUMPTION OF SMOKE.

A FAVOURITE employment of Mr. Watt in the workshops at Soho in the latter months of 1783 and earlier ones of 1784, was to teach his steam-engine, now become nearly as docile as it was powerful, to work a tilt-hammer for forging iron and making steel. So far back as 3 May, 1777, he had informed Mr. Boulton that "[John] Wilkinson is going to work in the forge way, and wants an engine to raise a stamp of 15 cwt. thirty or forty times in a minute. I have set Webb to work to try it with the little engine and a stamp-hammer of 60 lbs. weight. Many of these *battering rams* will be wanted if they answer." During his long absence, and constant occupation in Cornwall, this labour seems to have been intermitted; and we do not find it resumed in earnest till November, 1782. Then "the rotative motion and mill part answered to every expectation, but the hammer-frame and anvil-block were not sufficiently secured, which, however, I have given orders for doing. And as the engine has a great overplus of power, I mean to increase the weight of the hammer to about 1½ cwt., and to cause it to make 250 or 300 strokes per minute, by diminishing the height it rises to 9 or 10 inches.

The present facts are: cylinder, 15 inches diameter, and 4 feet stroke, 25 strokes per minute; hammer makes 6 blows per stroke of the engine; fly under 5 cwt., and 7 feet diameter; hammer 120 lbs., and 18 inches wide; it strikes a good blow, and forges iron very well. The *camms* were wood, and were cut all to pieces by the anvil-block sinking. I have ordered steel ones to be made, which I expect will stand it." * On the 30th of November he says,—"I saw the tilt go admirably from 16 to 25 strokes per minute, and it could have gone much faster, but our men could not work the iron under it. Joseph said that yesterday they made it go 28 strokes per minute, which is much more than the engine should do by my calculations; but in the midst of our glory, the hammer helve broke: it appears to have been rotten. The steel *camms* answer very well, and the whole will answer better when made to have a less lift and more strokes, as it will then answer for a common tilt for steel; at present the blow is so strong, that we dare not attempt to *hack* a piece of iron under 1½ inch square, otherwise it knocks it to pieces. By the help of some more weight on the outer end of the beam, it goes so regular that you cannot tell when the engine is going out or when coming in." On the 12th of December,—"I went out to Soho yesterday forenoon, hoping the engine would be ready for trial, but it was not. In the evening they wrought it 2 hours, 240 blows per minute, rise of hammer 8 inches." On the 13th,—"We have tried our little tilting-forge hammer at Soho, with success. The following are some of the particulars:—cylinder 15 inches diameter, 4 feet stroke, strokes per minute 20. The hammer-head, 120 lbs. weight, rises 8 inches, strikes 240 blows per minute. The machine goes quite regular, and can be managed as easily as a water-mill. It requires a very small quantity of steam, not above half the contents of the cylinder per stroke. The power employed is not more than ¼ of what would be required to raise the quantity of water which would enable a water-wheel to work the same hammer with the same velocity." Next month, they were "making another to work a hammer of 700 lbs., which will soon be at work." This was for Mr. John Wilkinson at Bradley, and, on the 27th of April, 1783, Mr. Watt writes, "We have had a trial of our new forge-engine at Bradley; cylinder 42 inches diameter, 6 feet stroke. Makes from 15 to 50 (even 60 strokes per minute) at pleasure, works a hammer of 7½ cwt. raised 2 feet high, which makes 6 strokes per stroke of the engine, and has struck 300 blows per minute; we are, however, going to make it strike only 4½ blows per stroke of the engine, because we want the latter to go 20 strokes per minute, and they want only 90 blows of the hammer in that time; but will increase the weight of the hammer to 10 cwt. N. B. The engine is to work two hammers, but is capable of working four hammers, of 7 cwt. each."

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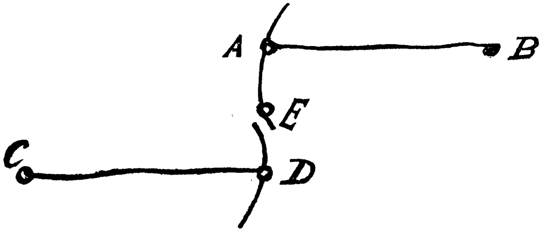
* To Mr. Boulton, 28 November, 1782.

In a letter written on the previous day, he had said, with excusable pride, "I believe it is a thing never done before, to make a hammer of that weight make 300 blows per minute; and, in fact, it is more a matter to brag of than for any other use, as the rate wanted is from 90 to 100 blows, being as quick as the workmen can manage the iron under it."

This most valuable application of steam-power was, accordingly, reserved for insertion in yet another patent, which Mr. Watt took out on the 28th of April, 1784. The relative specification, enrolled on the 25th of August in that year, may probably be viewed as second in importance to none of those prepared by Mr. Watt subsequent to that of the Separate Condenser in 1769; as, besides many improvements now of minor consequence, such as steam-wheels, balancing of pump-rods, communication of motion from the same engine to two separate primary axes, and apparatus for opening the regulating-valves with rapidity, it contains various methods of converting a circular or angular motion into a perpendicular or rectilineal motion,—one of those methods being the well-known and much-admired *Parallel Motion;*—a method of working a tilt-hammer for forging iron, making steel, &c., by steam;—and the application of the steam-engine to give motion to wheel carriages for carrying persons or goods.

Of the last-mentioned invention, and of its inventor's views of the subject of locomotion by steam, in general, we shall presently treat. Of the invention of the Parallel Motion,—a beautiful mechanical puzzle which different philosophers have attempted to explain in various ways, but which has uniformly commanded the admiration of all who either comprehend the principles on which it acts, or behold the smoothness, orderly power, and "sweet simplicity" of its movements,—we find the following account in a letter from Mr. Watt to his son, already cited; (Mr. Watt to Mr. James Watt, 10th November, 1808:)

"The idea originated in this manner. On finding double chains, or racks and sectors, very inconvenient for communicating the motion of the piston-rod to the angular motion of the working-beam, I set to work to try if I could not contrive some means of performing the same from motions turning upon centres, and after some time it occurred to me that AB, CD, being two equal radii revolving on the centres B and C, and connected together by a rod AD, in moving through arches of certain lengths, the variations from the straight line would be nearly equal and opposite, and that the point E would describe a line nearly straight, and that if for convenience the radius CD was only half of AB, by moving the point E nearer to D, the same would take place; and from this the construction, afterwards called the parallel motion, was derived. * * Though I am not over



anxious after fame, yet I am more proud of the parallel motion than of any other mechanical invention I have ever made."

See also on this subject Mr. Watt's Appendix on 'Robison on Steam and Steam-engines,' pp. 152, 153, where he mentions that "the invention was made in the latter end of 1783."

The manner in which we find the contrivance of this admirable piece of mechanism first recorded in his correspondence, although six months later than the date thus assigned to it by Mr. Watt, is interesting:—"I have started a new hare. I have got a glimpse of a method of causing a piston-rod to move up and down perpendicularly, by only fixing it to a piece of iron upon the beam, without chains, or perpendicular guides, or untowardly frictions, arch-heads, or other pieces of clumsiness; by which contrivance, if it answers fully to expectation, about five feet in the height of the [engine-] house may be saved in 8-feet strokes, which I look upon as a capital saving; and it will answer for double engines as well as for single ones. I have only tried it in a slight model yet, so cannot build upon it, though I think it a very probable thing to succeed, and one of the most ingenious simple pieces of mechanism I have contrived, but I beg nothing may be said on it till I specify."* And again, on the 11th of July:—"I have made a very large model of the new substitute for racks and sectors, which seems to bid fair to answer. The rod goes up and down, quite in a perpendicular line, without racks, chains, or guides. It is a perpendicular motion derived from a combination of motions about centres, very simple, has very little friction, has nothing standing higher than the back of the beam, and requires the centre of the beam to be only half the stroke of the engine higher than the top of the piston-rod when at lowest, and has no inclination to pull the piston-rod either one way or another except straight up and down. It has rather more power at beginning and end of the stroke than in the middle,—I think about one-sixth; which I believe will do no hurt in rotative motions, and little in any case. Beams mounted in this way need no arches; and the whole iron-work will not, I think, be more than chains, martingales, and their appendages, if quite so much. However, don't pride yourself on it; it is not fairly tried yet, and may have unknown faults. Where it is used, the beams will be best above the centre of motion, which will answer double engines very well, and may in most cases be dispensed with in the others." On the 21st of October, 1784, he writes:—"The new central perpendicular motion answers beyond expectation, and does not make the shadow of a noise." *

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* To Mr. Boulton, 30 June, 1784.

The manufacturing profits which Boulton and Watt stipulated to receive from the Cornish miners who used their engines, were at first one-third of the savings of fuel made by each engine, when compared with a common one burning the same kind of coal, to be paid annually or half-yearly, with an option of redemption at ten years' purchase. In point of fact, they did not receive nearly that proportion; but still, such was the agreement made, and such, had it been honestly adhered to on the side of the miners, would have been the amount paid. It therefore became essential to ascertain the exact number of strokes made by each engine during any given time, and that in a way that should be independent of all possibility of deception or interference by those employed about the engine. This object was fully attained by Mr. Watt's invention of his "Counter;" a neat piece of clock-work containing a pendulum, a train of wheels with an escapement, and several dials like those of watches graduated with numbers, and each with its index: the first index marking, on its own dial, tens; the next, hundreds; the next, thousands; and so on in the same ratio up to any required amount. Eight dials, with their respective indices, were found sufficient to count the strokes of an engine going constantly, day and night, for a

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* The specification of the patent of April 28th, 1784, is printed in the 'Mechanical Inventions of James Watt,' 1854, vol. iii., pp. 88 to 114; and the relative drawings are engraved on Plates XX., XXI., XXII., XXIII., XXIV., XXV., XXVI., XXVII., and XXVIII.

year. The pendulum was fixed horizontally and transversely across the width of the beam, with the axes of the wheels vertical, while the beam was horizontal, and the piston at the middle of a stroke; thus at every inclination of the beam either downwards or upwards, the pendulum moved across the width of the box, and, by the vibratory movement of the pendulum and pallets, the escapement wheel was turned one tooth for each complete stroke of the piston. And the whole work of the counter being enclosed in a box which was fastened by screws from within on the great beam of the engine and then locked, was inaccessible except to those in possession of the key.

Some other equally ingenious inventions, introduced by Mr. Watt at various periods, very greatly increased the utility of the engine; and although it would be vain here to attempt to give anything like a complete enumeration of his almost endless contrivances connected with the details of the different parts, yet we may mention especially, as among the leading improvements, the Throttle-Valve, the application of the Governor, the Barometer or Float, the Steam-Gauge, and the Indicator.

The great use of the Throttle-Valve was to regulate the speed of the rotative engines for mill-work, a matter essential to their application to cotton-spinning and many other like purposes; it is described by Mr. Watt as "a circular plate of metal, having a spindle fixed across its diameter, the plate being accurately fitted to an aperture in a metal ring of some thickness, through the edgeway of which the spindle is fitted steam-tight, and the ring fixed between the two flanches of the joint of the steam-pipe which is next to the cylinder. One end of the spindle, which has a square upon it, comes through the ring, and has a spanner fixed upon it, by which it can be turned in either direction. When the valve is parallel to the outsides of the ring, it shuts the opening nearly perfectly; but when its plane lies at an angle to the ring, it admits more or less steam according to the degree it has opened; consequently the piston is acted upon with more or less force. For many purposes engines are thus regulated by hand at the pleasure of the attendant; but where a regular velocity is required, other means must be applied to open and shut it, without any attention on the part of those who have the care of it.

"For this purpose Mr. Watt had various methods, but at last fixed upon what he calls the Governor, consisting of a perpendicular axis, turned by the engine: to a joint near the top of this axis are suspended two iron rods carrying heavy balls of metal at their lower ends, in the nature of pendulums. When this axis is put in motion by the engine, the balls recede from the perpendicular by the centrifugal force, and, by means of a combination of levers fixed to their upper end, raise the end of a lever which acts upon the spanner of the throttle-valve, and shuts it more or less according to the speed of the engine, so that as the velocity augments, the valve is shut, until the speed of the engine and the opening of the valve come to a maximum, and balance each other. The application of the centrifugal *principle* was not a new invention, but had been applied by others to the regulation of water and wind mills, and other things; but Mr. Watt improved the mechanism by which it acted upon the machines, and adapted it to his engines."

"Such," says M. Arago,—in describing Mr. Watt's application to the steam-engine of the "*governor*," or "regulator by centrifugal force,"—"was its efficacy, that there was to be seen at Manchester a few years ago, in the cotton-mill of Mr. Lee, a man of great mechanical talents, a clock which was set in motion by the steam-engine used in the work, and which marked time very well, even beside a common pendulum clock." *

"From the beginning, Mr. Watt applied a gauge to show the height of the water in his little boiler, which consisted of a glass tube communicating at the lower end with the water in the boiler, and at the upper end with the steam contained in it. This gauge was of great use in his experiments, but in practice other methods are adopted. He has always used a barometer to indicate the degree of exhaustion in his engines. Sometimes that instrument is, as usual, a glass tube 33 or 34 inches long, immersed at bottom in a cistern of mercury, and at top communicating by means of a small pipe and cock with the condenser. The oscillations are in a great degree prevented by throttling the passage for the steam by means of the cock.

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* Translation of the 'Eloge of Watt,' p. 87, ed. 1839.—Mr. Lee was a brother of Sophia and Harriet Lee, the well-known authoresses of the 'Canterbury Tales,' (1797-1805,) and of several other works.

" But, as glass tubes were liable to be broken by the workmen, barometers were made of iron tubes, in the form of inverted syphons, one leg about half the length of the other; to the upper end of the long leg a pipe and cock were joined, which communicated with the condenser; a proper quantity of mercury was poured into the short leg, of the syphon, and naturally stood level in the two legs: a light Float with a slender stem was placed in the short leg and a scale, divided into half-inches, applied to it, which (as by the exhaustion the mercury rose as much in the long leg as it fell in the short one) represented inches on the common barometer.

" The Steam-Gauge is a short glass tube with its lower end immersed in a cistern of mercury, which is placed within an iron box screwed to the boiler steam-pipe, or to some other part communicating freely with the steam, which, pressing on the surface of the mercury in the cistern, raises the mercury in the tube, (which is open to the air at the upper end,) and its altitude serves to show the elastic power of the steam over that of the atmosphere.

" These instruments are of great use when they are kept in order, in showing the superintendent the state of the engine; but slovenly engine-tenders are but too apt to put them out of order, or to suffer them to be so. It is the interest, however, of every owner of an engine to see that they, as well as all other parts of the engine, are kept in order.

" The barometer being adapted only to ascertain the degree of exhaustion in the condenser where its variations were small, the vibrations of the mercury rendered it very difficult, if not impracticable, to ascertain the state of the exhaustion of the cylinder at the different periods of the stroke of the engine; it became therefore necessary to contrive an instrument for that purpose that should be less subject to vibration, and should show nearly the degree of exhaustion in the cylinder at all periods. The following instrument, called the Indicator, is found to answer the end sufficiently. A cylinder about an inch diameter, and six inches long, exceedingly truly bored, has a solid piston accurately fitted to it, so as to slide easy by the help of some oil; the stem of the piston is guided in the direction of the axis of the cylinder, so that it may not be subject to jam, or cause friction in any part of its motion. The bottom of this cylinder has a cock and small pipe joined to it, which, having a conical end, may be inserted in a hole drilled in the cylinder of the engine near one of the ends, so. that, by opening the small cock, a communication may be effected between the inside of the cylinder and the indicator.

"The cylinder of the indicator is fastened upon a wooden or metal frame, more than twice its own length; one end of a spiral steel spring, like that of a spring steel-yard, is attached to the upper part of the frame, and the other end of the spring is attached to the upper end of the piston-rod of the indicator. The spring is made of such a strength, that when the cylinder of the indicator is perfectly exhausted, the pressure of the atmosphere may force its piston down within an inch of its bottom. An index being fixed to the top of its piston-rod, the point where it stands, when quite exhausted, is marked from an observation of a barometer communicating with the same exhausted vessel, and the scale divided accordingly."

"The joints of the cylinder, and other parts of Newcomen's engines, were generally made tight by being screwed together upon rings of lead covered with glazier's putty, which method was sufficient, as the entry of small quantities of air did not materially affect the working of those engines where only a very imperfect exhaustion was required. But the contrary being the case in the improved engines, this method would not answer Mr. Watt's purpose. He at first made his joints very true, and screwed them together upon pasteboard, softened by soaking in water, which answered tolerably well for a time, but was not sufficiently durable. He therefore endeavoured to find out some more lasting substance; and, observing that at the iron founderies they filled up flaws by iron borings or filings moistened by an ammoniacal liquor, which in time became hard, he improved upon this by mixing the iron borings or filings with a small quantity of sulphur and a little sal-ammoniac, to which he afterwards added some fine sand from the grindstone-troughs. This mixture being moistened with water and spread upon the joint, heats soon after it is screwed together, becomes hard, and remains good and tight for years; which has contributed in no small degree to the perfection of the engines. Mr. Murdock, much about the same time, without communication with Mr. Watt, made a cement of iron borings and sal-ammoniac, without the sulphur. But the latter gives the valuable property of making the cement set immediately."

To those who study the physiological development of the mind, every fact in the history of an intellect such as that of Mr. Watt, is of peculiar interest. For of all the mental powers, the faculty of mechanical inventiveness is perhaps the most rare; and Mr. Watt has long been, by the consent of the greatest men of science in the world, placed "at the head of all inventors in all ages and nations." * It thus becomes worth remarking, that the ten years subsequent to 1775, during which he took out his five last patents, and made those other improvements on the steam-engine of which we have now given some account, were the period during which he seems to have combined the greatest maturity with the greatest activity of intellect; and that the time of his life which they comprehended, was from his fortieth to his fiftieth year. The labour involved in devising and adapting to practice his new inventions, and in preparing the drawings and descriptions of them required for the specifications of his patents, was, indeed, only a small part of that which he then under-

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* Sir James Mackintosh, Speech at the Meeting at Freemasons' Hall, 1824.

went; for he was, for a great portion of the time, as we have already mentioned, daily occupied in superintending the erection of new engines or the alteration of old ones,—in watching and defeating the continual attempts made to pirate his inventions and rob his partner and himself of their moderate gains,—in "giving," as his son has said, "the constant attention necessary to the concerns of a nascent manufactory, and himself writing volumes of other letters on business, which alone would have furnished full employment even to an industrious intellect." "His mind also," continues the same excellent authority, "had been greatly affected by his unavoidable absence from the death-bed of his aged father;* and during the greater part of the time, I well remember seeing him suffer under most acute sick headaches, sitting by the fireside for hours together, with his head leaning on his elbow, and scarcely able to give utturance to his thoughts. It was unquestionably the busiest as well as the most anxious period of his life, and fraught with the most important results."

Often, in the course of the period of which we have been speaking, especially towards its close, we find him uttering complaints of his bad health, of what he calls his own "stupidity," and "want of the inventive faculty;" complaints which, had they issued from less sincere lips, might have been almost deemed ironical, but were with him, like everything else that he uttered, the honest expression of the true feelings of his mind. Towards the close of 1785, he says, "my own health is so bad that I do not think I can hold out much longer, at least as a man of business." "I cannot help being dispirited, because I find my head fail me much; business an excessive burden to me, and little prospect of any speedy release from it. Were we both young and healthy, I see no reason to despair, but very much the contrary; however, we must do the best we can, and hope for quiet in Heaven, when our weary bones are laid to rest;"—"on the whole, I find it now full time to cease attempting to invent new things, or to attempt anything which is attended with any risk of not succeeding, or of creating trouble in the execution. Let us go on executing the things we understand, and leave the rest to younger men, who have neither money nor character to lose." Early in 1786, also, he writes:—"in the anguish of my mind amid the vexations occasioned by new and unsuccessful schemes, like Lovelace, I 'curse my inventions,' and almost wish, if we could gather our money together, that somebody else should succeed in getting our trade from us." And, in June of the same year, "I should have written to you long ago, but have really been in a worse situation in some respects this spring than I have ever been in my life. The illness I was seized with in London in the spring greatly weakened me both in body and mind; and, I believe, was brought on by over-exertions, endeavouring to get home as soon as possible. The bodily disease has in great measure subsided; but an unusual quantity of business, which by Mr. Boulton's frequent and long absences has fallen wholly on me, and several vexations, with the consequent anxious thoughts, have hitherto prevented my mind from recovering its energy. I have been quite effete and listless, neither daring to face business, nor capable of it; my head and memory failing me much; my stable of hobby-horses pulled down, and the horses given to the dogs for carrion. In such a situation it requires something very pressing, or very animating, to make one put pen to paper. I have had serious thoughts of throwing down the burthen I find myself unable to carry, and perhaps, if other sentiments had not been stronger, should have thought of throwing off the mortal coil; but, if matters do not grow worse, I may perhaps stagger on. Solomon said that in the increase of knowledge there is increase of sorrow: if he had substituted *business* for knowledge, it would have been perfectly true."

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* Mr. Watt, senr., died in Greenock in August, 1782. On the 1st of September his son writes, on receiving the intelligence of that event, to Mr. Cochrane: "Yesterday brought me your letter of the 23rd, containing the afflicting news of the death of my worthy and kind father. When we consider his death as a removal from a state of pain and disease to a state where we must hope that he will meet the reward of a well-spent and laborious life, we cannot with reason bewail his loss; yet there is something so afflicting in the thought of the final, solemn departure of a beloved friend and revered parent, that though I have been, by his long illness and declining state, prepared for the event, the account of it has given me much pain. * *

"It behoves me now, however, to lay aside unavailing regret, and to thank God that he has hitherto preserved me from signal misfortunes.

"My wife and family are all well, and my children are promising, which circumstances I have great reason to be grateful for, however I may be otherwise afflicted."

The history of one other patent will exhaust the series of those taken out by Mr. Watt. On the 25th of March, 1785, he wrote to Mr. Boulton, "I think we are in the way of getting quit of smoke in the engines;" and on the 10th of September in the same year, to Mr. De Luc, "I have some hopes of being able to get quit of the abominable smoke which attends fire-engines. Some experiments which I have made promise success. It is not on Mr. Argand's principle, but on an old one of my own, which is exceedingly different." On the 9th of October, "We had a first trial yesterday of a large furnace to burn without smoke under the big boiler, at Soho, that used to poison Mr. B.'s garden so much, and it answered very well, as far as we could judge from a wet furnace, and without the engines being at work."

Of the date of this invention being devised or completed by Mr. Watt, we have no more exact information; but in September of the same year in which he obtained his patent for it, he mentioned that the principle on which it proceeded was "an old one of his own." Until that time, he does not appear ever to have tried it on a large scale; but, both then and since, it has, we believe, been always found to answer well in practice. "It is astonishing," writes his son Mr. James Watt to him from Manchester in 1790, "what an impression the smoke-consuming power of the engine has made upon the minds of everybody hereabouts; nobody would believe it until the engine was set a-going, and even then they scarcely trusted to the evidence of their senses. You would be diverted to hear the strange hypotheses which have been started to account for it. However, it has answered one extremely good end,—it has made your engines general topics of conversation, and consequently universally known; which they were by no means before in this country." And on the 14th of June, 1785, he took out a patent "for certain newly-improved methods of constructing furnaces or fire-places for heating, boiling, or evaporating of water and other liquids which are applicable to steam-engines and other purposes, and also for heating, melting, and smelting of metals and their ores, whereby greater effects are produced from the fuel, and the smoke is in a great measure prevented or consumed," which newly improved methods he describes to consist "in causing the smoke or flame of the fresh fuel, in its way to the flues or chimney, to pass together with a current of fresh air through, over, or among fuel which has already ceased to smoke, or which is converted into coke, charcoal, or cinders, and which is intensely hot, by which means the smoke and grosser parts of the flame, by coming into close contact with, or by being brought near unto the said intensely hot fuel, and by being mixed with the current of fresh or unburnt air, are consumed or converted into heat, or into pure flame free from smoke."

"I put this in practice," he continues,—"First, by stopping up every avenue or passage to the chimney or flues, except such as are left in the interstices of the fuel, by placing the fresh fuel above, or nearer to the external air, than that which is already converted into coke or charcoal; and by constructing the fire-places in such manner that the flame, and the air which animates the fire, must pass downwards, or laterally or horizontally, through the burning fuel, and pass from the lower part, or internal end or side of the fire-place, to the flues or chimney. In some cases, after the flame has passed through the burning fuel, I cause it to pass through a very hot tunnel, flue, or oven, before it comes to the bottom of the boiler, or to the part of the furnace where it is proposed to melt metal, or perform other office, by which means the smoke is still more effectually consumed. In other cases I cause the flame to pass immediately from the fire-place into the space under a boiler, or into the bed of a melting or other furnace." He varied the figure or form and proportions of the fire-places, &c., but in all cases the principle was the same; the fresh or raw fuel being placed next to the external air, and so that the smoke or flame passed over or through the coked or charred part of the fuel.

"Secondly," he goes on, "in some cases I place the fresh fuel on a grate as usual, and beyond that grate, at or near the place where the flame passes into the flues or chimneys, I place another small grate, on which I maintain a fire of charcoal, coke, or coals which have been previously burnt until they have ceased to smoke; which, by giving intense heat and admitting some fresh air, consumes the smoke of the first fire.

"Lastly, be it remembered," he concludes, "that my said new invention consists only in the method of consuming the smoke and increasing the heat, by causing the smoke and flame of the fresh fuel to pass through very hot tunnels or pipes, or among, through, or near fuel which is intensely hot, and which has ceased to smoke, and by mixing it with fresh air when in these circumstances; and in the form and nature of the fire-places herein mentioned, described, and delineated: the boilers and other parts of the furnaces being such as are in common use. And be it also remembered, that these new invented fire-places are applicable to furnaces for almost every use or purpose."*

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* The Specification, which was enrolled on the 9th of July, 1785, is printed in the 'Mechanical Inventions of James Watt,' 1854, vol. iii. pp. 115 to 121; and the relative drawings are engraved on Plates XXX., XXXI., XXXII., and XXXIII. of the same work.

CHAPTER XX.

HISTORY OF THE DISCOVERY OF THE COMPOSITION OF WATER—MR. WATT'S STUDY OF CHEMISTRY—STATE OF THAT SCIENCE PREVIOUS TO 1783—BLACK AND PRIESTLEY—MACQUER—VOLTA—WARLTIRE—CAVENDISH—DREW NO CONCLUSION FROM HIS EXPERIMENTS—LAVOISIER—HIS KNOWLEDGE OF THE EXPERIMENTS OF CAVENDISH.

In 1783,—one of the busiest of those ten years of his life which may thus be said to have teemed with experiments and inventions,—Mr. Watt had the further honourable distinction of making and publishing his famous discovery of the Composition of Water. It must be added, though we do so with regret, that, as in his greatest mechanical inventions, so in this matter also, he experienced the unpleasant necessity of vindicating his own just claims from the unexpected, and, as we believe, most men will be of opinion, the unjustifiable interference of others. It was an occasion, however, on which the firmness, moderation, and true greatness of his mind were signally manifested; and the circumstances of which, as displayed in his Correspondence on the subject, have contributed in every way to increase his good name.

His principal inventions connected with the steam-engine, with all their prodigious results, were founded, as we have seen, on the attentive observation of great philosophical truths; and the economy of fuel, increase of productive power, and saving of animal labour, which gradually ensued, all originated in the sagacious and careful thought with which he investigated the nature and properties of heat. The department of physical science with which, next to mechanics, he may be said to have been at one time most familiar, and which long continued in some measure to occupy his leisure hours, was Chemistry. With what success he studied it, we know from the testimony of the most eminent among his contemporaries who directed their attention especially to that subject, and many of whom were his frequent correspondents. "He was equally distinguished," said the late illustrious President of the Royal Society, Sir Humphry Davy, "as a natural philosopher and a chemist, and his inventions demonstrate his *profound knowledge* of those sciences."* The numerous experiments which he made with a view to the attainment of the great principles of which he was in search, are further commended by the same accomplished and able judge, as difficult, delicate, and refined.

In establishing himself at Soho, he retained his habits of intimate correspondence with Dr. Black, who had then, for more than twenty years, made known his discovery of carbonic acid gas, and for at least sixteen had annually explained his theory of latent heat in his lectures, in which, also, for the first time, he developed the doctrine of the capacities of bodies for heat, (or that of specific heat); and who, after spending ten years of academical labour in the University of Glasgow, had, in 1766, accepted that professorial chair in Edinburgh, which for thirty years longer he continued to render famous.

We have much pleasure in being able, on indisputable authority, to attribute the public announcement of Dr. Black's theory of latent heat to a period considerably earlier than had formerly been named, even by Dr. Black's zealous admirer and pupil, Lord Brougham. His Lordship says that Dr. Black meditated on that theory, investigated it by experiment, and taught it in his lectures, at least as early as 1763. But the following extract from his letter to Mr. Watt, of 15th March, 1780, furnishes information more precise, and assigns with certainty a much earlier date to so admirable a discovery. "I began," says the Doctor, "to give the doctrine of latent heat in my lectures at Glasgow, in the winter 1757-58, which I believe was the first winter of my lecturing there, or, if I did not give it that winter, I certainly gave it in the 1758-59, and I have delivered it every year since that time in my winter lectures, which I continued to give at Glasgow until winter 1766-67, when I began to lecture in Edinburgh."

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* Speech in 1824—Translation of Arago's 'Eloge,' p. 191.

Before proceeding to the history of the manner in which Mr. Watt was more immediately led to form and state in writing his conclusions respecting the composition of water, which had previously always been looked upon as an *element* or simple substance, it is proper that we should shortly relate the steps which had been taken, before the year 1783, towards a more accurate knowledge of its real nature.

The first observation of the moisture which is formed when inflammable air or hydrogen gas is burnt in common air, was made by M. Macquer, an excellent French physician and chemist, whose good sense and judicious experiments rendered great service to science, at a time when few minds had as yet shaken off any of the fetters of the old philosophy. In that edition of his '*Dictionnaire de Chimie*' which was published in 1778, and of which his translator, Mr. Keir, says, that it had been much esteemed, and had perhaps contributed more to the diffusion of chemical knowledge than any other book, (and which, as well as its author, was always spoken of by Dr. Black with the greatest respect,) he details, under the article 'Inflammable Gas,' many experiments on its combustion, which were made in 1776-7, and in which he was assisted by M. Sigaud de Lafond. "I assured myself also," he says, "by placing a saucer of white porcelain in the flame of inflammable gas burning tranquilly at the orifice of a bottle, that the flame is not accompanied by any fuliginous smoke; for that part of the saucer which the flame licked, remained perfectly white; it was only moistened by small drops of a liquor as clear as water, and which, in fact, appeared to us to be only pure water."[*] The phenomenon was certainly a remarkable one, and its observation appears now, as it did to Lavoisier in 1783,[†] to have nearly approximated to a most interesting inquiry, which might, indeed, have ended in the discovery afterwards so famous. But Macquer drew no conclusion from it, takes no further notice of it, and seems not even to have hazarded a speculation on its cause.

He also mentions the combustion of mixtures both of inflammable gas and common air, and of inflammable gas and dephlogisticated air or oxygen gas; and describes the explosion by which it was in both cases attended; that being, however, very much more violent in the latter case than in the former. He seems to have fired the airs in glass vessels, but although on one occasion he speaks of having done so in close vessels, it is evident from his further account of the experiment, that the vessel employed had a narrow aperture, to which a lighted match was applied.

Volta, in a letter dated 10th December, 1776, which is printed in Dr. Priestley's third volume,[‡] says, that he then fired inflammable air by the simple electric spark.

The next considerable step in the progress towards the grand discovery, was made by an English chemist and philosophical lecturer, Mr. Warltire, whose mode of conducting his experiments on the combustion of gases was highly creditable to his ingenuity. He fired a mixture of common and imflammable airs in a close metal flask or globe, by the electric spark; and, his object being to ascertain "whether heat was heavy or not," he says, "I always accurately balanced the flask of common air, then found the difference of weight after the inflammable air had been introduced, that I might be certain I had confined the proper proportion of each. The electric spark having passed through them, the flask became hot, and was cooled by exposing it to the common air of the room; it was then hung up again to the balance."

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[*] 'Dictionnaire de Chymie,' tom. ii., p. 314; ed. Neuchâtel, 1789.

[†] Lavoisier, 'Mémoires de l'Académie' for 1781, printed in 1784, p. 469.

[‡] Priestley's 'Experiments on Air, &c.,' 1781, vol. iii. p. 381.

Mr. Warltire adds, that in his experiments of this sort, he always found a small loss of weight, but not constantly the same; the vessel held three wine pints, and weighed fourteen ounces, and the average loss which he thought he detected was only two grains.

These experiments are detailed in a letter dated Birmingham, 18th April, 1781, which was addressed to Dr. Priestley, and published by him in the appendix to the second volume of his 'Experiments and Observations relating to various branches of Natural Philosophy; with a continuation of the Observations on Air;' printed at Birmingham in 1781. From the same letter it appears, that Priestley was the first to fire air in a close *glass* vessel, and to observe a deposit of water; but that Warltire, on repeating the same experiment, obtained the same result. "I have fired air in *glass* vessels," says Mr. Warltire, "since I saw you venture to do it, and have observed, as you did, that though the glass was clean and dry before, yet after firing the air, it became dewy, and was lined with a sooty substance." Dr. Priestley adds, that Mr. Warltire, "the moment he saw the moisture on the inside of the close glass vessel in which I afterwards fired the inflammable air, said that it confirmed an opinion he had long entertained, viz., that common air deposits its moisture when phlogisticated;" both inquirers being evidently impressed with the belief that the dew was nothing else than the mechanical deposit of the moisture dispersed in common air.

On the publication of Dr. Priestley's work in 1781, Mr. Cavendish proceeded in July of that year, and at subsequent times, to examine Mr. Warltire's experiment, (the object of which, it will be remembered, was to determine whether heat was ponderable,) frequently repeating it, with changes in some parts of the apparatus, and in the mode of preparation of the airs employed.

Mr. Cavendish's journal, or collection of laboratory notes, in which the details of all these experiments were entered, has been preserved among his papers. The whole of those papers were accurately examined, his Grace the late Duke of Devonshire having granted permission, for the purpose of ascertaining whether any of them contained anything indicative of the dates of Mr. Cavendish's *conclusions*, respecting the theory of the formation of water by the combustion of hydrogen and oxygen gases; but Mr. Charles Hatchett "could not find anything in them which referred to any date connected with the time when Mr. Cavendish probably first conceived his theory;"* and another gentleman, Mr. Hudson, in whose hands the papers had been placed by the Duke of Devonshire, and who minutely investigated them with every wish to discover some support to the claims which had been put forth on behalf of Mr. Cavendish, said, "I do not find in these journals of the experiments anything more than the simple statement of the facts, without any casual mention of theoretical opinions." This material fact has since been placed beyond the possibility of doubt, by the publication of the journal in question; in the whole course of which Mr. Cavendish does not make a single inquiry into the cause of the appearance of the water, nor indicate the most remote suspicion of its real origin; never using any expressions which could imply an union of the two airs, or which are inconsistent with the notion which Warltire and Priestley had entertained, of a mere mechanical deposit of the water. We are fully borne out in this assertion by the opinion of Lord Brougham, who says, "I must add, having read the full publication with fac-similes, Mr. Harcourt has now clearly proved one thing, and it is really of some importance. He has made it appear that in all Mr. Cavendish's diaries, and notes of his experiments, not an intimation occurs of the composition of water having been inferred by him from those experiments earlier than Mr. Watt's paper of Spring 1783."†

It is, further, apparent from the very title of his paper, '*Experiments on Air*,' that the composition of water was not the principal object to which Mr. Cavendish's attention had been directed. In this respect, his paper presents an obvious contrast to that of

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* Letter to Mr. James Watt, junr., 16th April, 1835.

† 'Lives of Men of Letters and Science,' vol. i. p. 401.

Mr. Watt, which bears the much more unequivocal title of 'Thoughts *on the Constituent Parts of Water*, and of Dephlogisticated Air;' and of which the great object is to maintain that doctrine of the composition of water which is distinctly stated in its outset.

M. Lavoisier, in his celebrated Memoir, admits that a partial communication was made by Blagden, to him and some other members of the French Academy, when, on the 24th of June, 1783, along with M. La Place, he tried the experiment which they reported to the Academy on the following day. "He informed us," says Lavoisier, "that Mr. Cavendish had already attempted to burn inflammable air in close vessels, and that he had obtained a very sensible quantity of water." He thus confines the extent of the communication within very narrow limits; for neither the experiment nor the result, as thus reported, was anything more than had been effected by Warltire and Priestley. Evidently he did not intend to admit that he knew of any *conclusion*, as to the real origin of the water, having been drawn by Cavendish; for in a subsequent part of the same memoir, he takes to his coadjutor and himself the credit of drawing such conclusion:—"we did not hesitate to conclude from it, that water is not a simple substance, and that it is composed, weight for weight, of inflammable air, and of vital air." He adds also, that they were then ignorant, and did not learn for some days, that M. Monge was occupied on the same subject.

CHAPTER XXI.

MR. WATT'S EXAMINATION OF DR. PRIESTLEY'S EXPERIMENTS IN MARCH AND APRIL, 1783—HIS CONCLUSIONS AS TO THE COMPOSITION OF WATER—HIS LETTER TO DR. PRIESTLEY—DELAY IN READING IT BEFORE THE ROYAL SOCIETY—KNOWN TO CAVENDISH, BLAGDEN, AND LAVOISIER, IN 1783—CAVENDISH'S PAPER OF JANUARY, 1784—APPARENT PLAGIARISM—CURIOUS DOUBLE TYPOGRAPHICAL ERRORS—BLAGDEN'S LETTER TO CRELL, 1786.

Mr. Watt, in whose neighbourhood Dr. Priestley says he had "the happiness to be situated," and with whom, as has been mentioned, he was on terms of friendship and frequent intercourse, had, previous to 1783, for many years entertained an opinion that air was a modification of water; and that, if steam could be made red-hot, so that all its latent heat should be converted into sensible heat, either the steam would be converted into permanent air, or some other change would take place in its constitution. "You may remember," he writes to Mr. Boulton,* "that I have often said, that if water could be heated red-hot or something more, it would probably be converted into some kind of air, because steam would in that case have lost all its latent heat, and that it would have been turned solely into sensible heat, and probably a total change of the nature of the fluid would ensue." And, so early as 13th December, 1782, he talks of processes "by which," he says, "I now believe air is generated from water;" using the expression, "if this process contains no deception, here is an effectual account of many phenomena, *and one element dismissed from the list.*" †

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* 10th December, 1782.

† Mr. Watt to Mr. De Luc, 13th December, 1782.

Being thus, even at that time, prepared to expect that water was, in some way or other, convertible into air, he directed his attention to Dr. Priestley's experiment, which he thus accurately relates: "He puts dry dephlogisticated air and dry inflammable air into a close vessel, and kindles them by electricity. No air remains, at least if the two were pure, but he finds on the sides of the vessel a quantity of water equal in weight to the air employed."[*] In less than a month after he thus mentions his knowledge of that experiment, we find him writing to Dr. Black that he believes he has found out the cause of the conversion of water into air;"[†] and giving the very words in which, both on that day, and a few days later, he stated his conclusions in the letter to Dr. Priestley, which he desired might be read to the Royal Society:—"In the deflagration of the inflammable and dephlogisticated airs, the airs unite with violence,—become red-hot,—and, on cooling, totally disappear. The only fixed matter which remains, is *water;* and *water*, *light*, and *heat*, are all the products. Are we not then authorized to conclude, that water is composed of dephlogisticated and inflammable air, or phlogiston, deprived of part of their latent heat; and that dephlogisticated, or pure air, is composed of water deprived of its phlogiston, and united to heat and light; and if light be only a modification of heat, or a component part of phlogiston, then pure air consists of water deprived of its phlogiston and of latent heat?" The same conclusions are given in other letters written nearly at the same time; but nowhere are they more clearly, briefly, or forcibly stated, than in that to Mr. Gilbert Hamilton of the 22nd of April, where, after a short enumeration of FACTS, beginning with the result of Dr. Priestley's experiment, follow these DEDUCTIONS.

"*Pure inflammable air is phlogiston itself.*

"*Dephlogisticated air is water deprived of its phlogiston, and united to latent heat.*

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[*] To his brother-in-law, Mr. Gilbert Hamilton, 26th March, 1783.

[†] 21st April, 1783.

"*Water is dephlogisticated air deprived of part of its latent heat, and united to a large dose of phlogiston.*"

In writing to Mr. De Luc, four days afterwards, "These," says Mr. Watt, "seem bold propositions, but I think they follow from the present state of the experiments; and if I were at leisure to write a book on the subject, I think I could prove that no experiment hitherto made contradicts them, and that the greater number of experiments affirm them."* To others of his correspondents he announced his theory in similar terms. To Mr. Smeaton, writing that he has "attempted to demolish two of the most ancient elements—air and water;"† and to Mr. Fry, giving particular directions for the production of water and of [dephlogisticated] air:—"Dr. Priestley, as you observe, converts water into air, and air into water, and I have found out the reason of all these wonders, and also what air is made of, and what water is made of; for they are not simple elements.—I have written a paper on the subject, and sent it with Dr. Priestley's to the Royal Society. It is too long to give you even an abstract of it, but if you will forgive me the reasoning, I will add the receipt below for making both these elements.

"*To make Water.*—

"R. Of pure air and of phlogiston Q. S., or if you wish to be very exact, of pure air one part, of phlogiston, in a fluid form, two parts, by measure. Put them into a strong glass vessel, which admits of being shut quite close; mix them, fire them with the electric spark; they will explode, and throw out their elementary heat. Give that time to escape, and you will find the water, (equal in weight to the air,) adhering to the sides of the vessel. Keep it in a phial close corked for use.

"*To make Air.*—

"Take pure water Q. V., deprive it of its phlogiston by any practicable method, add elementary heat Q. S. and distil. You will obtain pure air, to be preserved as above."*

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* 26th April, 1783.

† 27th April, 1783.

It will be remembered, that in the letter to Mr. Hamilton he had shown his belief to be, that pure inflammable air and phlogiston were exactly synonymous; and it is very remarkable, that the proportions of the two gases which he directs to be fired, viz., of pure air one part, and of inflammable air two parts, by measure, are exactly those which chemists of the present day would employ.

It appears from the letter to Dr. Black of the 21st of April, that Mr. Watt had, on that day, written his letter to Dr. Priestley, to be read by him to the Royal Society; but on the 26th he informs Mr. De Luc, that having observed some inaccuracies of style in that letter, he had removed them, and would send the Doctor a corrected copy in a day or two, which he accordingly did on the 28th; the corrected letter, (the same that was afterwards embodied verbatim in the letter to Mr. De Luc, printed in the Philosophical Transactions,) being dated 26th April, and containing, almost at its very commencement, the following passages:—

"The same ingenious philosopher mixed together certain proportions of pure dry dephlogisticated air and of pure dry inflammable air in a strong glass vessel, closely shut, and then set them on fire by means of the electric spark. The first effect was the appearance of red heat or inflammation in the airs, which was soon followed by the glass vessel becoming hot. The heat gradually pervaded the glass, and was dissipated in the circumambient air, and as the glass grew cool, a mist or visible vapour appeared in it, which was condensed on the glass in the form of moisture or dew. When the glass was cooled to the temperature of the atmosphere, if the vessel was opened, with its mouth immersed in water or mercury, so much of these liquids entered, as was sufficient to fill the glass within about $\frac{1}{200}$th part of its whole contents; and this small residuum may safely be concluded to have been occasioned by some impurity in one or both kinds of air. The moisture adhering to the glass, after these deflagrations, being wiped off, or sucked up, by a small piece of sponge paper, first carefully weighed, was found to be exactly, or very nearly, equal in weight to the airs employed. In some experiments, but not in all, a small quantity of a sooty-like matter was found adhering to the inside of the glass. The whole quantity of sooty-like matter was too small to be an object of consideration, particularly as it did not occur in all the experiments.

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* 28th April, 1783.

"Let us now consider what obviously happens in the case of the deflagration of the inflammable and dephlogisticated air. These two kinds of air unite with violence; they become red-hot, and upon cooling totally disappear. When the vessel is cooled a quantity of water is found in it equal to the weight of the air employed. The water is then the only remaining product of the process, and *water*, *light*, and *heat* are all the products.

"*Are we not, then, authorised to conclude that water is composed of dephlogisticated air and phlogiston, deprived of part of their latent or elementary heat; that dephlogisticated or pure air is composed of water deprived of its phlogiston, and united to elementary heat and light; and that the latter are contained in it in a latent state, so as not to be sensible to the thermometer or to the eye; and if light be only a modification of heat, or a circumstance attending it, or a component part of the inflammable air, then pure or dephlogisticated air is composed of water deprived of its phlogiston and united to elementary heat.*"

In enclosing it, Mr. Watt adds, "As to myself, the more I consider what I have said, I am the more satisfied with it, as I find none of the facts repugnant."

"To those," wrote Mr. James Watt, junr., in an interesting letter addressed to the author of this biography,* "who may wish to form a just appreciation of the circumstances in which this correspondence took place, and of the merit that attaches to my father for the discovery it records, I beg to state, in the words of the great master of the English tongue, that 'it was written, not in the soft obscurities of retirement, or under the shelter of academick bowers; but amidst inconvenience and distraction, in sickness and in sorrow.' About the beginning of the year, when the correspondence commences, he had returned from planning and superintending the erection of his steam-engines, during a long sojourn in Cornwall, where he had been much harassed by attempts to pirate his improvements; and he was, through the greater part of the subsequent period, laboriously engaged in making out drawings and descriptions for the long specifications of his three great patents for mechanical improvements and inventions, taken out in the years 1781, 1782, and 1784, besides giving the constant attention necessary to the concerns of a nascent manufactory, and himself writing volumes of other letters on business, which alone would have furnished full employment even to an industrious intellect. His mind had been greatly affected by his unavoidable absence from the death-bed of his aged father; and during the greater part of the time, I well remember seeing him suffer under most acute sick head-aches, sitting by the fire-side for hours together, with his head leaning on his elbow, and scarcely able to give utterance to his thoughts. It was unquestionably the busiest, as well as the most anxious, period of his life, and fraught with the most important results. I need not attempt to do justice to them, for time has sanctioned the judgment of his contemporaries, who had done it already."

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* Dated Aston Hall, 5 February, 1846, and printed with Mr. Watt's 'Corre-

But,—to return to Mr. Watt's letter to Dr. Priestley, of 26th April, 1783,—"This letter," as is stated in Mr. Watt's Note published in the Philosophical Transactions, "Dr. Priestley received at London; and, after showing it to several members of the Royal Society, he delivered it to Sir Joseph Banks, the

spondence on his Discovery of the Theory of the Composition of Water,' published in the same year, pp. i. to xvi.

President, with a request that it might be read at some of the public meetings of the Society." [*]

But, as it happened, the public reading which had been so requested by Mr. Watt did not take place at that time. "Before that could be complied with," the note continues, "the author, having heard of Dr. Priestley's new experiments, begged that the reading might be delayed."

The new experiments alluded to in the note, Priestley had announced in these terms:—"Behold with surprise and indignation the figure of an apparatus that has utterly ruined your beautiful hypothesis," [†] giving a rough sketch with his pen of the apparatus employed. But Mr. Watt immediately and unhesitatingly replied, "I deny that your experiment ruins my hypothesis. It is not founded on so brittle a basis as an earthen retort, nor on *its* converting water into air. I founded it on the other facts, and was obliged to stretch it a good deal before it would fit this experiment. * * * I maintain my hypothesis until it shall be shown that the water formed after the explosion of the pure and inflammable airs, has some other origin." [‡] So to Mr. De Luc:—"I do not see Dr. Priestley's experiment in the same light that he does. It does not disprove my theory. * * My assertion was simply, that air" [*i. e.*, dephlogisticated air, or oxygen, which was also commonly called vital air, pure air, or simply *air*,] "was water deprived of its phlogiston, and united to heat, which I grounded on the decomposition of air by inflammation with inflammable air, the residuum, or product of which, is only water and heat." [§] Even when writing to Dr. Black that he had withdrawn his paper, he adds, "I have not given up my theory." [‖]

But he did withdraw, or rather reserve the public reading of his paper, till he should further examine the new experiments which were said to be hostile to the doctrine which it unfolded; and also, as he adds with his usual modesty, because he was "informed that that theory was considered too bold, and not sufficiently supported by facts." * "Mr. Watt then wished," as it is more fully expressed in a work published shortly afterwards, "that the letter should not be read at the public meeting of the Society, because he learned that his theory was thought too bold, or that a substance such as water, till then considered as of the nature of an *element*, was there placed in the class of *compounds*." † But the letter itself, after being read by many members, remained in the custody of the President till the day when it was read to the Society, 22nd April, 1784, as is well ascertained from Mr. Watt's letter to Blagden of 27th May, 1784.

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[*] 'Philosophical Transactions,' 1784, p. 330.—Note.

[†] Dr. Priestley to Mr. Watt, 29th April, 1783.

[‡] Mr. Watt to Dr. Priestley, 2nd May, 1783.

[§] To Mr. De Luc, 18th May, 1783.

[‖] To Dr. Black, 23rd June, 1783.

But in the meantime, having by additional experiments still further satisfied himself of the correctness of his theory, in which he had never been able to detect error, and the truth of which he now held to be abundantly confirmed, he proceeded, towards the end of November, tranquilly to occupy himself in preparing a more full statement of it, to be sent to his friend De Luc, for the purpose of being read to the Royal Society. By the 1st of December, however, we find that he had received accounts of an occurrence which appeared to stand much in need of explanation; and which, after that had been obtained, proved little to the credit of some of those concerned. "I was," he says, in writing to Mr. De Luc, ‡ "at Dr. Priestley's last night. He thinks, as I do, that Mr. Lavoisier, having heard some imperfect account of the paper I wrote in the Spring, has run away with the idea, and made up a memoir hastily, without any satisfactory proofs. How that may be, I cannot take on me to say; but if you will read the 47th and 48th pages of Mr. De la Place's and his Memoir on Heat, you will be convinced that they had no such ideas then, as they speak clearly of the nitrous acid being converted into air. I therefore put the query to you of the propriety of sending my letter to pass through their hands to be printed; for even if this theory is Mr. Lavoisier's own, I am vain enough to think that he may get some hints from my letter, which may enable him to make experiments, and to improve his theory, and produce a memoir to the Academy before my letter can be printed, which may be so much superior as to eclipse my poor performance, and sink it into utter oblivion; nay, worse, I may be condemned as a plagiary, for I certainly cannot be heard in opposition to an Academician and a Financier. * * But, after all, I may be doing Mr. Lavoisier injustice. * * I see it, on the one hand, so difficult to satisfy those nice chemists, and, on the other hand, so difficult to be allowed even the honour of the discovery, that I am nearly discouraged, either from publishing at all, or trying any more experiments; as it seems to be losing my labour and procuring myself disquiet." "M. Lavoisier," he also writes, "has read a memoir opening a theory very similar to mine on the composition of water; indeed, so similar, that I cannot help suspecting he has heard of the theory I ventured to form on that subject, as I know that some notice of it was sent to France." *

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* Mr. Watt to Sir Joseph Banks, 12th April, 1784.

† De Luc, 'Météorologie,' tom. ii., p. 216. 1786.

‡ 30th November, 1783.

To this conjecture, Mr. Kirwan was able, in his reply, to add the most positive assurance. "M. Lavoisier," he writes, "certainly learned your theory from Dr. Blagden, who first had it from Mr. Cavendish, and afterwards from your letter to Dr. Priestley, which he heard read, and explained the whole minutely to M. Lavoisier last July." [June.] †

The letter was, of course, well known to Dr. Priestley, who received it, perused it, and at once occupied himself in answering it, and to Sir Joseph Banks, in whose hands it long remained. But that it was also read by many other members of the Royal Society, though not then at a public meeting of the body, there cannot be any manner of doubt. For we have not only the

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* To Mr. Kirwan, 1st December, 1783.

† Mr. Kirwan to Mr. Watt, 13th December, 1783.

direct statement of Mr. Watt to that effect, published in the Philosophical Transactions in 1784, under the direct superintendence of Dr. Blagden, and repeated by Mr. De Luc in 1786,* but we have Blagden admitting his own knowledge of the paper, both in the statement which he says he made to Lavoisier in June, and in his letter which Crell printed in 1786.

Mr. De Luc having gone to Paris in December, 1783, and there passed the month of January, 1784, returned to England in February, when his letters to Mr. Watt were resumed. In the meantime, on the 15th January, Mr. Cavendish had read to the Royal Society the first part of his celebrated 'Experiments on Air,' of which the second part was not read till the 2nd of June, 1785. In one of Mr. De Luc's letters, dated 1st March, 1784, he mentions that he had heard some particulars of the paper which Mr. Cavendish had read, but nothing concerning *the conclusions* stated in it as to the composition of water appears to have been then reported to him. The imperfect account which he thus received came from Dr. Blagden. As the paper, however, was said to have included a thorough examination of the combustion of the two airs, he requested Mr. Cavendish's permission to see it, which was granted.

The consternation into which he was thrown on perusing it for the first time is well depicted in the close of the same letter:—"Being at this point of my letter, I have received Mr. Cavendish's paper, and have read it!! . . . . Expect something that will astonish you as soon as I can write to you. . . . Meanwhile, tell no one. . . . *In short, he expounds and proves your system, word for word, and makes no mention whatever of you.*"

Mr. De Luc, in his letter of the 1st March, had promised an analysis of Cavendish's paper, and on the same day began a long transcript of its principal parts, which he finished on the 4th March, and sent to Mr. Watt in a letter, which showed that, on a further examination, his amazement had not subsided. Having endeavoured, in some degree, to defend Lavoisier and La Place from the charge of *le Plagiat*, he says:—"But that which is, on the other hand, perfectly clear, precise, astonishing, is the memoir of Mr. Cavendish. *Your own terms, in your letter of April to Dr. Priestley, given as something new, by some one who must have known that letter, which was known to all the active members of the Royal Society—to Dr. Blagden above all,* (for he said he had spoken of it to Messrs. Lavoisier and La Place,) who well knew Mr. Cavendish's memoir, both before it was read to the Royal Society, and at its reading, and who conversed with me about it, as I told you in my last—me, whom he knows to be your zealous friend."

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* 'Météorologie,' vol. ii., p. 216.

In the very delicate and disagreeable circumstances which had thus occurred, Mr. De Luc suggested two modes of proceeding: the one, to suffer in silence the injustice which he could not but feel had been done, in which case he engaged to print the letters to Dr. Priestley and himself, with their dates, in a work he was then preparing; the other, to make the matter more public, by requesting Sir Joseph Banks to cause both the letters to be read to the Royal Society. In recommending the former, the too discreet philosopher used these words:—"I should almost advise it, considering that, in your position of drawing from your discoveries practical consequences for your fortune, you must avoid making yourself *des jaloux*."

He had yet to learn the full extent of the manly virtue of his friend; who, while he declined to make any attack upon Mr. Cavendish, admitting, perhaps with a somewhat extravagant liberality, that it was "barely possible" that he might not have heard of his theory, still spoke in a strain of honest indignation of the plagiarism which he felt there was too much room to believe had been effected, of the wound which his scientific fame had been made to suffer, and of the hardship of being thus anticipated in the first attempt he had made to lay anything before the public. "As to what you say," he wrote, "about making myself *des jaloux*, that idea would weigh little; for, were

I convinced I had had foul play, if I did not assert my right, it would either be from a contempt for the modicum of reputation which would result from such a theory, from a conviction in my own mind that I was their superior, or from an indolence that makes it more easy for me to bear wrongs, than to seek redress. In point of interest, so far as connected with money, that would be no bar: for though I am dependent on the favour of the public, I am not on Mr. C. or his friends, and could despise the united power of *the illustrious house of Cavendish,* as Mr. Fox calls them. You may, perhaps, be surprised to find so much pride in my character. It does not seem very compatible with the diffidence that attends my conduct in general. I am diffident, because I am seldom certain that I am in the right, and because I pay respect to the opinions of others, where I think they may merit it. At present, *je me sens un peu blessé;* it seems hard, that in the first attempt I have made to lay anything before the public, I should be thus anticipated. It will make me cautious how I take the trouble of preparing any thing for them another time." *

What followed may be very briefly told: "He states his intention of being in London in the ensuing week, and his opinion, that the reading of his letter to the Royal Society will be the proper step to be taken. He accordingly went there, waited upon the President of the Royal Society, Sir Joseph Banks, was received with all the courtesy and just feeling which distinguished that most honourable man, and it was settled, that both the letter to Dr. Priestley of 26th April, 1783, and that to Mr. De Luc of 26th November, 1783, should be successively read. The former was done on the 22nd, and the latter on the 29th April, 1784:" † and it is said by Sir Joseph Banks, that "both appeared to meet with great approbation from large meetings of Fellows." ‡

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* Mr. Watt to Mr. De Luc, 6th March, 1784.

† Note by Mr. James Watt, junr., added to Lord Brougham's Historical Note.—See Translation of Arago's 'Eloge,' p. 164.

‡ Sir Joseph Banks to Mr. Watt, 11th May, 1784.

Both of the letters were ordered by the Committee of Papers to be printed, and it was arranged that the best form in which that could be done, in order to avoid repetition, was by incorporating the first with the second, which was accordingly the plan adopted; "but," as the note in the Philosophical Transactions bears, "to authenticate the date of the author's ideas, the parts of it which are contained in the present letter are marked with double commas."

Blagden became Secretary of the Royal Society on the 5th of May, 1784; and to him, in virtue of his office, was entrusted the superintendence of the printing of Mr. Watt's paper. In his letters on that subject, he appeared perfectly willing to attend with care to the publication; and in one of them offered, should Mr. Watt desire it, to send him the proof-sheets for correction. Mr. Watt, residing at a distance from town, declined his offer; a resolution which he had afterwards reason to regret; for the consequence has been, that in his paper, as it stands in the Philosophical Transactions, there is a very unfortunate *error of the press*. The date of the letter to Mr. De Luc, which we have just seen, was 26th November, 1783, is there given as 26th November, 1784. It is true that the date of the *reading* of the paper is rightly given; it has also been lately discovered that the misprint is noticed in the errata at the end of the volume of the Philosophical Transactions in which it appears; and therefore that error might not always mislead; but, considering all that had previously occurred, it was of great importance that every date establishing Mr. Watt's priority shall be accurately printed, and what we shall in this instance call carelessness, even if freed from blame, must on every account remain matter of regret.

But this is not all. Of Mr. Cavendish's paper there were a number of separate copies thrown off, which were widely circulated throughout Europe by himself and his friends, before the seventy-fourth volume of the Philosophical Transactions, in which it was to be contained, made its appearance. These also, it is presumed, had been printed under the superintendence of Dr.

Blagden, and of Mr. Cavendish. They all bear on their title-page, that Mr. Cavendish's paper was "read at the Royal Society, January 15, 1783." Moreover, the true date, 1784, which is placed at the head of that paper as it stands in the Philosophical Transactions, is not given at all in those separate copies.

But we have not yet done with either the history of the discovery, or the share which Dr. Blagden took in it as an auxiliary and historian. Finding that Lavoisier still maintained some claim, and seeing from the note appended to Mr. Watt's paper, and from the total want of any statement as to the chronology of Cavendish's conclusions, that Mr. Watt stood distinctly recorded as the first discoverer, notwithstanding the inexplicable awkwardness of the typographical errors, Blagden thought proper to write the letter to Dr. Lorenz Crell, printed two years later in his Journal, of which the following is a translation :*—

"I can certainly give you the best account of the little dispute about the first discoverer of the artificial generation of water, as I was the principal instrument through which the first news of the discovery that had been already made was communicated to Mr. Lavoisier. The following is a short statement of the history :—

"In the Spring ('Frühjahr') of 1783, Mr. Cavendish communicated to me and other members of the Royal Society, his particular friends, the result of some experiments with which he had for a long time been occupied. He showed us, that, out of them, he must draw the conclusion, that dephlogisticated air was nothing else than water deprived of its phlogiston; and, *vice versâ*, that water was dephlogisticated air united with phlogiston. About the same time ('um dieselbe Zeit') the news was brought to London, that Mr. Watt of Birmingham had been induced by some observations, to form ('fassen') a similar opinion. Soon after this ('bald darauf') I went to Paris, and in the company of Mr. Lavoisier, and of some other members of the Royal Academy of Sciences, I

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[*] The letter appears not to have been dated; but it was published in Crell's 'Chemische Annalen,' Helmstädt u. Leipzig, 1786, pp. 58-61.

gave some account of these new experiments, and of the opinions founded upon them. They replied that they had already heard something of these experiments; and, particularly, that Dr. Priestley had repeated them. They did not doubt that in such manner a considerable quantity of water might be obtained; but they felt convinced that it did not come near to the weight of the two species of air employed; on which account it was not to be regarded as water formed or produced out of the two kinds of air, but was already contained in, and united with the airs, and deposited in their combustion. This opinion was held by Mr. Lavoisier, as well as by the rest of the gentlemen who conferred on the subject; but, as the experiment itself appeared to them very remarkable in all points of view, they unanimously requested Mr. Lavoisier, who possessed all the necessary preparations, ('Vorrichtungen,') to repeat the experiment on a somewhat larger scale, as early as possible. This desire he complied with on the 24th June, 1783, (as he relates in the latest volume of the Paris Memoirs.) From Mr. Lavoisier's own account of the experiment, it sufficiently appears, that at that period he had not yet formed the opinion, that water was composed of dephlogisticated and inflammable airs; for he expected that a sort of acid would be produced by their union. In general Mr. Lavoisier cannot be convicted of having advanced any thing contrary to truth; but it can still less be denied that he concealed a part of the truth. For he should have acknowledged that I had, some days before, apprized him of Mr. Cavendish's experiments; instead of which, the expression 'il nous apprit,' gives rise to the idea that I had not informed him earlier than that very day. In like manner Mr. Lavoisier has passed over a very remarkable circumstance, namely, that the experiment was made in consequence of what I had informed him of. He should likewise have stated in his publication, not only that Mr. Cavendish had obtained 'une quantité d'eau très sensible,' but that the water was equal to the weight of the two airs added together. Moreover, he should have added, that I had made him acquainted with Messrs. Cavendish and Watt's conclusions; namely, that water, and not an acid or any other substance, ('Wesen,') arose from the combustion of the inflammable and dephlogisticated airs. But *those* conclusions opened the way to Mr. Lavoisier's present theory, which perfectly agrees with that of Mr. Cavendish, only that Mr. Lavoisier accommodates it to his old theory, which banishes phlogiston. Mr. Monge's experiments, (of which Mr. Lavoisier speaks as if made about the same time,) were really not made until pretty long, I believe at least two months, later than Mr. Lavoisier's own, and were undertaken on receiving information of them. The course of all this history will clearly convince you, that Mr. Lavoisier, (instead of being led to the discovery, by following up the experiments which he and Mr. Bucquet had commenced in 1777,) was induced to institute again such experiments, solely by the account he received from me, and of our English experiments; and that he really discovered nothing but what had before been pointed out to him to have been previously made out, and demonstrated in England."

Now, before examining the history which this letter gives of the discovery, it is to be observed that it professes to have been written in order to give *the best account* of the dispute about *the first discoverer*. And from the relations in which Blagden stood to Cavendish, and the obligations he owed him, he cannot be suspected of under-stating any claims which he might have been able to establish for that gentleman to the possession of so great an honour.

Bearing this in mind, and taking the statement as we find it, an extraordinary fact which meets us at the outset is, that it does not contain any distinct allegation of Cavendish having been *the first discoverer;* although it does positively assert that he was prior to Lavoisier, and appears to aim at having it understood that he was prior also to Mr. Watt. Even the time at which Cavendish is reported to have communicated to his friends of the Royal Society his experiments and their results, and "showed that out of them he must draw the conclusion," is only noted in the most general way, as "in the Spring of 1783." But we know that

Mr. Watt's conclusions, on the other hand, were actually formed, reduced to writing, (which Cavendish's confessedly were not,) and known to many members of the Royal Society, also "in the Spring of 1783;" and Blagden, though he was well aware of all these circumstances, and professes to give "the best account," and was naturally desirous of gaining the credit of the priority for his patron, does not even state that *Cavendish's verbal communication* preceded his knowledge of *Mr. Watt's written conclusions.*

CHAPTER XXII.

ARGUMENTS OF THE ADVOCATES OF CAVENDISH—THEIR GROUNDLESSNESS—PRIORITY OF WATT MAINTAINED DURING HIS LIFETIME—OPINIONS OF PHILOSOPHERS SINCE HIS DEATH—DR. HENRY—SIR HUMPHRY DAVY—LORD BROUGHAM—ARAGO—DUMAS—BERZELIUS—SIR DAVID BREWSTER—LORD JEFFREY—LIEBIG—MR. WATT'S SCRUPULOUS SENSE OF JUSTICE—HIS ACQUAINTANCE WITH CAVENDISH—FESTIVITIES OF THE ROYAL SOCIETY.

BESIDES employing the argument arising from the reputation of Mr. Cavendish, which does not really affect the question of priority in the discovery, if established by other evidence, the advocates of Cavendish have made three principal assertions with the view of impugning M. Arago's accuracy. They have said, first, that Priestley "constantly maintained" that he had never found the weight of the water, produced in his experiment, equal to that of the gases exploded; secondly, that an undue licence had been used, in substituting the term *hydrogen* for *phlogiston*, as used by Mr. Watt; and thirdly, that the conclusions of Cavendish, which were first stated to the Royal Society in his paper read on the 15th of January, 1784, must be supposed to have been included, or involved, in his experiments made in 1781.

The first of these assertions might well be termed by M. Arago "inconceivable," when it is remembered that in Priestley's own paper he says,—"In order to judge more accurately of the quantity of water so deposited, and to compare it with the weight of the air decomposed, I carefully weighed a piece of filtering paper, and then having wiped with it all the inside of the glass vessel in which the air had been decomposed, weighed it again; and *I always found, as near as I could judge, the weight of the decomposed air in the moisture* acquired by the paper." [*] In the very first pages of Mr. Watt's paper "on the Constituent Parts of Water," in describing Dr. Priestley's experiment, it is said,—"The moisture adhering to the glass after these deflagrations, being wiped off, or sucked up by a small piece of sponge paper, first carefully weighed, was found to be *exactly, or very nearly, equal in weight to the airs employed.*" And,—"These two kinds of air unite with violence, they become red-hot, and, upon cooling, totally disappear. When the vessel is cooled, *a quantity of water is found in it equal to the weight of the air employed.*" [†] So in Mr. Watt's Correspondence, "he finds on the side of the vessel *a quantity of water equal in weight to the air employed.*" [‡] And again, "No residuum, except a small quantity of *water equal to their weight.*" [§] So also, "you will find *the water, equal in weight to the air,*) adhering to the sides of the vessel." [‖] The circumstance of the equality of weight was indeed one of the facts on which Mr. Watt repeatedly states that he founded his deductions; and, as will presently be seen, it is of great importance in more points of view than one.

The substitution of the term *hydrogen* for *phlogiston*, had been so amply explained by M. Arago, in the note on that subject which accompanied Lord Brougham's Historical Note,[¶] that it might have been supposed no fair objection could have been raised to it by any one; even by the most injudicious and ill-informed partisan of Mr. Cavendish. M. Arago was also at the pains to produce a letter from Dr. Priestley to M. Lavoisier, dated 10th July, 1782, in which he says he has made "some experiments with inflammable air, that seem to prove *that it is the same thing that has been called phlogiston.*" Dr. Priestley, in relating, in his paper of 1785, the theory which Mr. Watt had formed, says that he "concluded, &c., that water consists of dephlogisticated *and inflammable air.*" But further, in Mr. Watt's own note, (given both in the 'Philosophical Transactions' and in Lord Brougham's Historical Note,) viz.: "Previous to Dr. Priestley's making these experiments, Mr. Kirwan had proved, by very ingenious deductions from other facts, that *inflammable air was, in all probability, the real phlogiston in an aërial form. These arguments were perfectly convincing to me.*"[*]

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[*] 'Phil. Trans.,' 1783, p. 427.
[†] 'Phil. Trans.,' 1784, pp. 332, 333.
[‡] Mr. Watt to Mr. Gilbert Hamilton, 26 March, 1783.
[§] The same to the same, 22 April, 1783.
[‖] Mr. Watt to Mr. Fry, 28 April, 1783.
[¶] 'Eloge of Watt,' p. 167.

So in Mr. Watt's paper we find these expressions:—"It was reasonable to conclude, that *inflammable air must be the pure phlogiston, or the matter which reduced the calces to metals;*"——"*the inflammable air being supposed to be wholly phlogiston;*"——"*inflammable air or phlogiston;*"——"it is worthy of inquiry whether the greater part of the heat let loose was not contained in *the phlogiston or inflammable air,*"[†] &c., &c. So, also, in writing to Dr. Black on the 21st of April, 1783,—he says, "therefore *inflammable air is the thing called phlogiston.*" So to Mr. Hamilton, on the 22nd of April, the first of the three deductions he states is, "*pure inflammable air is phlogiston itself.*"

It is evident that the term *hydrogen*, derived from the Greek word for water, and designating one of its constituents, could not have been invented till after the composition of that fluid had been ascertained. Lavoisier himself, the inventor of the term, did not use it till a later period; and he expressly says, in the beginning of his paper, "The inflammable air which I understand when I mention it in this Memoir, is that which is obtained, either from the decomposition of water by iron alone, or from iron and zinc dissolved in vitriolic and marine acids; and, as it appears proved that in all cases that air comes originally from water, I shall call it, when it presents itself in the aëriform state, *aqueous inflamma-*

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[*] 'Phil. Trans.,' 1784, p. 331.

[†] Ibid., pp. 349, 350, 352.

ble air; and when it is engaged in any combination, *aqueous inflammable principle.*"

But in what respect was Cavendish superior to Mr. Watt on this point? Even in 1784 he used neither the term hydrogen at all, nor uniformly the term inflammable air; for his conclusion is in that year thus stated:—"There seems the utmost reason to think that dephlogisticated air is only water deprived of its *phlogiston,* and that inflammable air is either phlogisticated water or else pure phlogiston; *but in all probability the former,*"—a conclusion infinitely more dim and distant from the truth than those which we have just cited from Mr. Watt's paper and letters.

Lastly, it has been asserted, that Cavendish's mere experiments, apart from the formation of any theory, "involved the notion, and established the fact," of the composition of water. So in some sense did Priestley's;—so did Warltire's; nay, on the same principles, it might be hard to withhold the merit of priority from Macquer and Sigaud de Lafond, who, by the combustion of gases, produced water which appeared to them to be pure. It may be true that Macquer's data, so far as he has recorded them, were scarcely sufficient to have led him readily to form a just opinion on the subject. But Priestley and Warltire, in their experiments of 1781, came very much nearer the last experimental step afterwards arrived at by Cavendish: the loss of weight which Warltire detected after the combustion was almost imperceptible, and was at once to be accounted for by the least imperfection in his apparatus. Yet they both confidently attributed the formation of the dew to the mere deposition of suspended moisture.

So late as 1784, Meusnier and Lavoisier, in the commencement of their Memoir on the Decomposition of Water,* remark, that "there have nevertheless been doubts raised on that entire reduction of two aëriform fluids into water; and, notwithstanding the precautions taken by M. Lavoisier, to ensure, as much as possible, precision in so délicate an experiment; notwithstanding the conformity of the result obtained nearly at the same time by M. Monge, in the laboratory of the school of Mézières, with a very exact apparatus and the most scrupulous attention, some persons have believed, that the water which proceeds from that operation may be attributed to humidity held in solution by the airs, and deprived of support at the moment of their combustion."

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* 'Mémoires de l'Académie' for 1781, published in 1784.

In the same year, Mr. Kirwan appears to have thought that he ventured far in admitting himself to be "nearly convinced," that, when the two gases are fired, "water is really produced." * The example of caution, which had been set by so many sage experimentalists, was further illustrated in the case of Dr. Black, who, in his correspondence with Mr. Watt, only remarks of the steps immediately preceding his discovery, that they appeared to him "very surprising;" and, in 1790, thus wrote to Lavoisier: "I long experienced a great aversion to the new system, which represented as erroneous that which I had regarded as a sound doctrine; nevertheless, that aversion, which was caused by the power of habit alone, has gradually diminished, yielding to the clearness of your demonstrations, and the solidity of your plan." †

Nay, the most conspicuous instance of the same truth, (at least in France, for it would be hard to point out a more signal one than Priestley,) is to be found in the case of M. Monge himself. He was perfectly aware of the *result* of the combustion of the two gases; having performed the experiment on a greater scale, and obtained its product in a larger quantity, than was done by any other at so early a date; and yet he appears, at a period as late as 1786, when his paper was printed, to have entertained very uncertain notions as to the nature of the change which was operated, and very great doubts as to the theory, which would now be so idly represented to have been obvious to any one, who performed the experiments on which *it might have been founded.* It is very interesting to find Monge in 1789 thus writing to Mr. Watt:—"The decomposition of water by the electric spark, of which you have no doubt heard by the 'Journal de Physique,' here stops the mouth of the few unbelievers whom we still had; and it is no longer doubtful, that that liquid is composed of oxygen and hydrogen:" * and then immediately expressing the profound veneration he entertained for the talents and virtues of his friend, whom he evidently looked upon as the true author of the theory which had at last been so completely established to the general satisfaction.

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* 'Phil. Trans.' for 1784, p. 167.

† 'Annales de Chimie,' viii. p. 227. It is said by Mr. Yeats, in his 'Observations on the Claims of the Moderns to some Discoveries in Chemistry and Physiology' (1798, p. 247), that when Lavoisier was informed, by this letter from Dr. Black, of his conversion to the anti-phlogistic doctrine, so great was his joy in having acquired such able support, that he published it in all the newspapers in Paris. It is an affecting incident, which we record on the same authority, that when Dr. Black, in an Introductory Lecture on Chemistry, came to the subject of the discoveries of Lavoisier, soon after that illustrious enquirer had become a victim to the fury of democratic tyranny,—the lecturer stopped, unable to proceed:—the generous feelings of a humane heart, recurring to the cruel circumstances of his death, prevented utterance.

In 1789, also, six years after the discovery had been made, Berthollet found occasion to write no fewer than fifty pages, (printed in the '*Annales de Chimie*' for that year,) in confutation of some of the arguments then maintained against it.

Fourcroy speaks of "that brilliant discovery, which had so many prejudices, so many obstacles, so many ancient errors, to overcome." † And, although he admits that within a few years it became the creed of a great part of the members of the Academy, he adds that they were obliged continually to defend it against the most desperate attacks. He himself soon followed the example of Berthollet, and of his friend Guyton-Morveau, whose conversion took place at the close of the year 1786."‡

It is thus impossible to say, that the experiments necessarily imply the conclusions; or to consider the right explanation of that most remarkable phenomenon as having been included in the mere observation of the preliminary fact.

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* 'Mechanical Inventions of Watt,' vol. ii. p. 237.

† 'Système des Connoissances Chimiques,' tome i. p. 37.

‡ Ibid. p. 40.

After all that has now been said, it can hardly be thought necessary that we should gravely answer the ridiculous assertion, that Mr. Watt did not in his lifetime put forward a distinct claim to the honour which was justly his due.

Mr. Watt's note in the 'Philosophical Transactions,' which most effectually declares his priority, was never contradicted nor called in question by Cavendish or any of his friends; to all of whom,—and especially, as we have seen, to Dr. Blagden,—it was well known, being printed in the same volume with both of the papers.* Having, by that note, done all that became so high-minded a man and so true a philosopher, he could well afford to despise any portion of fame that might have been gained by more elaborate or less worthy means. "When the theory of the composition of water was spoken of in the presence of my father," said Mr. James Watt, junior, "he calmly but uniformly sustained his claim to its discovery; and once, on my hinting that it was passed over by some writers, and not correctly given by others, he observed, that having done all that he and his friends considered requisite to place it upon record, by the note affixed to his paper of 26th November, 1783, in the 'Philosophical Transactions,' the accuracy of which had never been questioned, *he should leave posterity to decide.*" †

After the death of Mr. Watt, his correspondence and the relative papers on this subject were submitted by his son to various learned persons, most competent to form a just opinion of their importance, and of the facts which they establish; to Sir Humphry Davy, Mr. Corrie, Sir David Brewster, and, among the rest, to Dr. William Henry of Manchester, who has been termed by Lord

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* It deserves to be mentioned, that in the Abridgment of the Papers in the 'Philosophical Transactions,' prepared by Hutton, Shaw, and Pearson, Mr. Watt's important note is, very improperly, omitted. This may account for Cavendish having received the credit of the priority, with some of those who on subjects of scientific interest do not consult original authorities.

† Letter to the author, 5 February, 1846 printed with the 'Correspondence on the Discovery of the Composition of Water.'

Jeffrey, "probably the very highest authority that could have been referred to on such a subject."

We have seen Dr. Henry's original letter of 8th June, 1820; in which, under his own hand, his opinion at that time is thus stated:—

"*There is no room for doubt as to your father's priority.*

"*It is established beyond all dispute, by a comparison of dates, that your father was the first to interpret rightly the important experiments showing the synthesis of water.*

"*I should say that yonr father was the first who had the sagacity to draw the right conclusion from the experiment of Dr. Priestley, and to take that view of the constitution of water, which, to this time, continues to be received by philosophers as the true one.*"

Sir Humphry Davy's opinion on the matter having been referred to, may, with propriety, here be noticed. In his 'Elements of Chemical Philosophy'* he slightly alludes (as many others have done in the same loose way of speaking) to Mr. Cavendish's two discoveries of the composition of water and of nitric acid. But in one of his lectures, supposed to have been written about 1806, the more particular account he gives is, that in 1781, "Mr. Cavendish, in a process conceived with his usual sagacity, and executed with his usual precision, showed that when common air and hydrogen were exploded together, in the proportion of two and a half to one, the product was pure water, which exactly corresponded in weight to the gas consumed. And Mr. Watt, reasoning on this experiment, formed the conclusion that water consisted of pure and inflammable air, deprived of the greatest portion of their latent heat." Now, the experiments on which Mr. Watt reasoned were, as has been seen, not Cavendish's, but Priestley's. But the great and important distinction is clearly drawn, between Mr. Cavendish's mere observation of a fact, and the explanation of it by the theory which Mr. Watt formed.

In the Memoir of Mr. Watt which was published in 1824, in the sixth edition of the 'Encyclopædia Britannica,' his just claims to the priority of the theory of the composition of water, are concisely but comprehensively detailed. They were made more widely known by the eloquent 'Eloge of Watt' read by the late lamented M. Arago before the Institute of France, on the 8th of December, 1834, and published in the 'Mémoires de l'Académie des Sciences,' as well as in the 'Annuaire du Bureau des Longitudes' for 1839, accompanied by the able and interesting Historical Note by Lord Brougham,* and by some other notes added by the late Mr. James Watt, junior. In January, 1840, on the occasion of M. Arago presenting to the Academy of Sciences a Translation into English of the 'Eloge,' the statement which it contained of Mr. Watt's claims received the emphatic corroboration of M. J. Dumas; who stated, that after having attentively examined the reasoning of his fellow-member, after having also scrupulously studied the correspondence preserved at Aston Hall,† he adopted "completely and in all its parts," the history which M. Arago had written of the discovery of the composition of water; and that his opinions upon that point were so decided, that he desired his declaration to be inserted in the Compte-Rendu of the meeting. "And a more authoritative deliverance," says Lord Jeffrey, "we suppose will not easily be found in any such register." ‡

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* Vol. iv. p. 30, of the edition of his collected works, published by his brother, Dr. John Davy.

The learned and philosophical chemist of Sweden, Berzelius, in 1841, on a deliberate review of the works then published on this subject, has, without hesitation, assigned to Mr. Watt that merit and priority of date, which so many other learned men have with justice attributed to him: saying that it is clear that he arrived at his conclusions eight months earlier than Cavendish, who could scarcely have been ignorant of them when he wrote his paper.

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* See Appendix.

† The original letters were submitted to his perusal by Mr. Watt, junior, as they had before been to M. Arago.

‡ 'Edinburgh Review' for January, 1848.

Sir David Brewster, on fully studying the fresh evidence which the correspondence of Mr. Watt first made public, unhesitatingly professed his entire conversion; and in one of those eloquent essays by which he has so often adorned the progress of scientific discovery, publicly announced, as the conclusion at which he had arrived, that the argument for Mr. Watt's priority "had now been placed on a sound and impregnable basis." *

After the appearance of Sir David's fervent and powerful appeal, another eminent person, the late lamented Lord Jeffrey, consecrated the last, and we believe the longest, as it certainly is one of the very ablest of all his critical labours, to an admirable and truly judicial review of the whole controversy, then well-nigh its close.†

Lastly, Liebig, in his 'Letters on Chemistry,' says, that "we value facts because of their permanence and immutability, and because they supply the soil for ideas; but *a fact acquires its true and full value only through the idea which is developed by it.* Many facts were not in the possession of Stahl, but the idea is his property. Cavendish and Watt both discovered the composition of water: *Cavendish established the facts, Watt the idea.* Cavendish says, 'From inflammable and dephlogisticated air water is produced.' Watt says, 'Water consists or is composed of inflammable and dephlogisticated air.' Between these forms of expression there is a wide difference."

Even as matters now stand, with a priority of publication really incontestable,—while it is by no means our wish to lessen the high reputation which Mr. Cavendish maintained,—we may be forgiven if we dwell with pride on some characteristics of Mr. Watt, which are not without a very important and obvious bearing on a question like the present.

A distinguished orator and statesman, after mentioning that he had the happiness of knowing Mr. Watt for many years, in the intercourse of private life, said that those who were admitted to his society would readily allow, that any thing more pure, more candid, more simple, more scrupulously loving of justice, than the whole habits of his life and conversation proved him to be, was never known:—"There was one quality, which most honourably distinguished him from too many inventors, and was worthy of all imitation,—he was not only entirely free from jealousy, but he exercised a careful and scrupulous self-denial, and was anxious not to appear, even by accident, as appropriating to himself that which he thought belonged to others. * * The only jealousy I have known him to betray, was with respect to others; in the nice adjustment he was fond of giving to the claims of inventors. Justly prizing scientific discovery above all other possessions, he deemed the title to it so sacred, that you might hear him arguing by the hour to settle disputed rights; and if you ever perceived his temper ruffled, it was when one man's invention was claimed by, or given to another; or when a clumsy adulation pressed upon himself that which he knew to be not his own." *

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* 'North British Review' for January, 1847, vol. vi. p. 497.

† 'Edinburgh Review' for January, 1848, vol. lxxxvii., pp. 67–137.

It is no derogation from his excellence, that he was at the same time not unconscious of "just pride, founded on great talents and great services; that pride, which the most exalted and most worthy can justly indulge." † But his exemplary mind borrowed an additional grace from his habitual restraint of all such emotions; and we shall never forget the noble animation with which one of our most gifted and venerable Poets, ‡ after having pointedly censured the unhappy passion for notoriety by which he conceived that some scientific men of the present day were too much actuated, fervently exclaimed,—"It was not so, that NEWTON made *his* discoveries, the grandest ever known; nor that WATT made *his*, the most beneficial to mankind:—I look upon him, considering both the magnitude and the universality of his genius, as perhaps the most extraordinary man that this country ever produced; he never sought display, but was content to work in that quietness and humility, both of spirit and of outward circumstances, in which alone all that is truly great and good was ever done."

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* Lord Brougham's Speech, printed with the Translation of Arago's 'Eloge,' pp. 216–218.

† Sir R. Peel, in the House of Commons, 23rd January, 1846.

‡ Mr. Wordsworth, in September, 1840.

The result of the evidence on the whole case, as far as Mr. Watt's priority is concerned, we shall briefly express in these propositions, which certainly do not assume more than we have already proved; and of which every one who has been accustomed to the exactness of legal inquiries into matters of disputed discovery, will acknowledge the force.

First, that Mr. Watt formed the original idea in his own mind, and thus was A DISCOVERER of the true theory of the composition of water.

Secondly, that being a discoverer, he was also THE FIRST PUBLISHER of that true theory.

Thirdly, that being both a discoverer, and also the first publisher, he must therefore be held to be "THE TRUE AND FIRST INVENTOR THEREOF." *

Thus, in the course of the controversy, all has been done that seemed essential for the fame of Mr. Watt, or that was requisite for a compliance with his own simple and memorable injunction, delivered nearly seventy years ago: †—"Preserve the dignity of a philosopher and historian; relate the facts, and leave posterity to judge."

It may somewhat relieve the dullness of scientific discussion, and also present a more cheerful view of human nature than some other parts of "the water controversy" afford, if we offer such confirmation as our present researches enable us to do, of the late Mr. James Watt's assertion that his father, "after becoming in 1785 a Fellow of the Royal Society, formed the personal acquaintance of Mr. Cavendish, and lived upon good terms

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* See Godson on Patents, pp. 27-30. The term "Inventor" is, of course, here used in the legal sense, of "one that has found out something new."

† To Dr. Darwin, 24 November, 1789.

with him."* In August of that year, it appears, Cavendish visited Birmingham and Soho, where he spent some time in examining the engine establishment, and conversing with Mr. Watt upon it:—and in October of the same year, Mr. W. wrote† as follows:—"When I was in London I was received very kindly by Mr. Cavendish and Dr. Blagden, and my old-friend Smeaton, who has now recovered his health, and seems hearty. I dined at a turtle feast with them and the select club of the Royal Society; and never was turtle eaten with greater sobriety and temperance, or more good fellowship. I dined also at Mr. Cavendish's, who lives very elegantly, and gave us a good English dinner. Among other company we had the famous Peter Camper, the Anatomist, once Professor at Franecker,‡ a fresh gigantic man of 64, that never had sickness in his life except once. He is to come here before leaving England."§

We had formerly regretted, that neither Mr. Watt, nor, so far as we then knew, any one else, had left any record of Mr. Cavendish's "flow of soul" on the evening in question; but we have since discovered, in a pocket-book for 1785, under date of 21st October, in Mr. Watt's hand-writing, this entry:—"Dined at Mr. Cavendish's, topic Hugenian telescope."

In point of convivial enjoyment, the other dinner mentioned in Mr. Watt's letter would appear, from his expressions, considerably to have excelled the entertainment supplied at Cavendish's eremitical abode. And we are not without other means of estimating the amount of good fellowship which habitually prevailed at those "noctes cœnæque Deûm" of the club of the

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* 'Correspondence of Mr. Watt on his Discovery of the Composition of Water,' p. iv.

† To Mrs. Watt, Birmingham, October 31st, 1785.

‡ In Friesland. Camper was born in 1722, and, in the same year in which he met Mr. Watt, was elected a member of the Academy of Sciences at Paris. He died in 1789, and is buried in St. Peter's Church, Leyden.

§ Which he accordingly did: as we learn from a letter of Mr. Watt to Mrs. Watt, dated Birmingham, November 3, 1785—"I had a visit of Professor Camper yesterday: he is a fine old fellow."

Royal Society. That distinguished mineralogist, M. Faujas de St. Fond, has devoted some pages of his 'Travels in Great Britain' to recording the scene he witnessed, and the impression it made upon him, when a few years later he partook of a like hospitality; and as, on the occasion of which he speaks, Sir Joseph Banks was President, Blagden Secretary, and Cavendish one of the party, and all of those three are among the persons of what we may term the drama of the discovery of the composition of water, we perhaps need not apologise for introducing some notice of that feast of scientific reason, which M. de St. Fond has minutely, and with evident relish, thus described.

At this "dinner of an academic club," which commenced at five o'clock, he says, "the dishes were of the solid kind, such as roast beef, boiled beef, and mutton prepared in various manners,—with abundance of potatoes and other vegetables, which each person seasoned as he pleased with the different sauces which were placed upon the table. The beef-steaks and the roast beef were at first sufficiently drenched by *large quantities of strong beer, called porter:* it was drank out of cylindrical pewter pots, *which are, by some, thought preferable to glasses, perhaps because they enable one to swallow a whole pint at a draught.* This prelude being finished," there appeared, "as if by magic, a number of fine crystal decanters filled with the best port, madeira, and claret." "Several glasses were distributed to each person, and *the libations commenced on a grand scale,* in the midst of different kinds of *cheeses, which, rolling in mahogany cases from one end of the table to the other, provoked the thirst of the drinkers.*" "The members of the club afterwards saluted each other, one by one, with a glass of wine. According to this custom, *one must drink as many times as there are guests,* for it would be thought a want of politeness in England to drink to the health of more persons than one at a time." M. de St. Fond had mentioned, in an earlier part of his account, that the club consisted of about forty members, each of whom had a right to introduce two, and the president a greater number of friends. He does not mention by how many the guests, and consequently the glasses of wine drank by each at this stage of the entertainment, fell short of the hundred and twenty to which that compotatory computation might amount. But, *qualis ab incepto*, the convivial narrative proceeds:—"*A few bottles of champagne soon put all the company in good humour.* The tea came next, with butter, marmalade, and all its usual accompaniments: coffee followed, humbly yielding precedence to the tea, though it be the better of the two. In France, we commonly drink only one cup of good coffee after dinner; in England, they drink five or six times that quantity, of the most detestable kind. *Brandy, rum, and some other strong liquors, closed this philosophic banquet.*" And for the solid repast with all its fluid accompaniments,—"all this intolerable deal of sack,"—each of the guests paid "seven livres, four sols French money." With justice does the good M. Faujas remark, "This was not dear;" and he sympathetically adds, "The great Corneille, Molière, Despreaux, La Fontaine, and Racine, used to take a bottle now and then in a tavern; and they were neither the worse friends, nor the worse poets, for it."

CHAPTER XXIII.

PROPOSED UNIFORMITY OF WEIGHTS AND MEASURES—THE LUNAR SOCIETY—DR. DARWIN—PRIESTLEY—RIOTS AT BIRMINGHAM—MR. WATT'S JOURNEY TO PARIS AT THE REQUEST OF THE FRENCH GOVERNMENT—MACHINE OF MARLY—BLEACHING BY CHLORINE—INFRINGEMENTS OF STEAM-ENGINE PATENTS—TRIALS AT LAW—PARTIES TO THE ACTIONS—ARGUMENTS AGAINST AND FOR THE VALIDITY OF THE PATENT OF 1769—NATURE OF THE EVIDENCE—J. BRAMAH—VERDICTS IN FAVOUR OF THE PATENTEES—VALIDITY OF THE PATENT OF 1769 CONCLUSIVELY ESTABLISHED.

MR. WATT's chemical studies in 1783 having led him, towards the end of that year, to make some calculations from experiments of Lavoisier and De La Place, and to compare them with others made by Mr. Kirwan, he wrote to the latter gentleman,* "I had a great deal of trouble in reducing the weights and measures to speak the same language; and many of the German experiments become still more difficult from their using different weights and different divisions of them in different parts of that empire. It is therefore a very desirable thing to have these difficulties removed, and to get all philosophers to use pounds divided in the same manner, and I flatter myself that may be accomplished if you, Dr. Priestley, and a few of the French experimenters will agree to it; for the utility is so evident, that every thinking person must immediately be convinced of it. My proposal is briefly this; let the

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* 14th November, 1783.

Philosophical pound	consist of	10 ounces,	or 10,000	grains.
the ounce	"	10 drachms,	or 1,000	"
the drachm	"	100 grains,	or 100	"

Let all elastic fluids be measured by the ounce measure of water, by which the valuation of different cubic inches will be avoided, and the common decimal tables of specific gravities will immediately give the weights of those elastic fluids.

"If all philosophers cannot agree on one pound or one grain, let every one take his own pound or his own grain; it will affect nothing except doses of medicines, which must be corrected as is now done; but as it would be much better that the identical pound was used by all, I would propose that the Amsterdam or Paris pound be assumed as the standard, being now the most universal in Europe: it is to our avoirdupois pound as 109 is to 100. Our avoirdupois pound contains 7000 of our grains, and the Paris pound 7630 of our grains, but it contains 9376 Paris grains, so that the division into 10,000 would very little affect the Paris grain. I prefer dividing the pound afresh to beginning with the Paris grain, because I believe the pound is very general, but the grain local.

"Dr. Priestley has agreed to this proposal, and has referred it to you to fix upon the pound if you otherwise approve it. I shall be happy to have your opinion of it as soon as convenient, and to concert with you the means of making it universal. * * * I have some hopes that the foot may be fixed by the pendulum and a measure of water, and a pound derived from that; but in the interim let us at least assume a proper division, which from the nature of it must be intelligible as long as decimal arithmetic is used."

"As to the precise foot or pound," he afterwards adds, in writing to Mr. Magellan, "I do not look upon it to be very material, in chemistry at least. Either the common English foot may be adopted according to your proposal, which has the advantage that a cubic foot is exactly 1000 ounces, consequently the present foot and ounce would be retained; or a pendulum which vibrates 100 times a minute may be adopted for the standard, which would make the foot 14.2 of our present inches, and the cubic foot would be very exactly a bushel, and would weigh 101 of the present pounds, so that the present pound would not be much altered. But I think that by this scheme the foot would be too large, and that the inconvenience of changing all the foot measures and things depending on them, would be much greater than changing all the pounds, bushels, gallons, &c. I therefore give the preference to those plans which retain the foot and ounce." Alas, at the distance of three-quarters of a century from such philosophical and practical proposals, the prospect of a universal system of weights and measures seems almost as remote as that of a universal language!

About the time when Mr. Watt presented to the Royal Society his memorable 'Thoughts on the Constituent Parts of Water,' the neighbourhood of Birmingham was remarkable for the number of kindred spirits, all devoted to the pursuit of natural knowledge, and filled with mutual esteem and affection, who there found profitable pleasure in each other's society. Besides Mr. Watt and Mr. Boulton, there were among that number Dr. Darwin, Dr. Withering, Mr. Keir, Mr. Galton, Mr. Edgeworth, and Dr. Priestley;—all of them luminaries not unworthy to revolve round Watt as their central sun, but also shining with more than merely reflected light. Priestley, who came to reside at Birmingham in 1780, and has repeatedly acknowledged the happiness he experienced in living near Mr. Watt, has thus noticed those monthly repasts of which his philosophical friends and himself partook at their respective houses in turn, and which became well known as the meetings of *the Lunar Society*. "I consider my settlement at Birmingham as the happiest event of my life; being highly favourable to every object I had in view, philosophical or theological. In the former respect I had the convenience of good workmen of every kind, and the society of persons eminent for their knowledge of chemistry; particularly Mr. Watt, Mr. Keir, and Dr. Withering. These, with Mr. Boulton and Dr. Darwin, who soon left us by removing from Lichfield to Derby, Mr. Galton, and afterwards Mr. Johnson, of Kenilworth, and myself, dined together every month, calling ourselves *the Lunar Society*, because the time of our meeting was near the full-moon,"* "in order," as he elsewhere says, "to have the benefit of its light in returning home." From an invitation from Mr. Watt to Mr. Wedgwood to attend one of the dinners of the Society, we learn that it was customary for the philosophic *convives* "to dine at two o'clock, and not to part till eight in the evening."

Mr. Watt, in writing to Dr. Darwin to remind him of his engagement to attend another of those friendly meetings, at once social and scientific, gives a lively bill of fare of the subjects proposed for the consideration of the party;—some expressions used in which, viz., "it is to be determined whether or not heat is a compound of phlogiston and empyreal air," "what light is made of, and also how to make it,"† as well as the still more curious ones of Darwin's reply, "I can tell you some secrets in return for yours, viz., that atmospheric gas is composed of light and the earth of water, (aqueous earth,)—*that water is composed of aqueous gas, which is displaced from its earth by oil of vitriol*,"‡—may be held to have foreshadowed, with more or less distinctness, those researches which ended in the discovery of "what water is made of," and also, as the discoverer quaintly expresses it, "how to make it."§

The Lunar Society lost one of its most active and valued members by the disgraceful riots which in 1791 had the effect of driving Priestley from his home; when his house, library, chemi-

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[*] 'Memoirs of Dr. Priestley, by himself.' p. 97. 1806.

[†] Mr. Watt to Dr. Darwin, Birmingham, January 3rd, 1781; 'Mechanical Inventions of Watt,' vol. ii. p. 123.

[‡] Dr. Darwin to Mr. Watt, Jan. 6, 1781; 'Mechanical Inventions of Watt,' vol. ii. p. 124.

[§] Mr. Watt to Mr. Fry of Bristol, p. 329, *suprà*.

cal apparatus, and furniture, were destroyed by the cowardly violence of the rabble. On that occasion the extraordinary spectacle was presented, of an ignorant and brutal mob in England arming themselves against the partisans of democratic lawlessness in France. "The affair originated," wrote Mr. Watt to his friend M. De Luc,* "from some gentlemen very foolishly celebrating the French revolution by a dinner on the 14th. They were warned that some tumult might ensue, and advised against it; however, some of them met, were insulted as they went in, and, therefore, dispersed by five o'clock. About eight o'clock a mob assembled, broke the windows of the hotel where the company met, pulled down two dissenting meeting-houses, then Dr. Priestley's house, which they razed to the ground, (he and his family made their escape in time;) then they destroyed a very good house in town, and from that proceeded to destroy some others in town, and some of the best houses in the country, mostly belonging to dissenters, they say to the number of ten or fifteen, and to the amount of above 100,000*l.* Then was the sovereignty of the people established in full authority for three days and nights! Quiet subjects were panic-struck; and, after some feeble efforts to establish peace, people submitted quietly to their fate. We, on our part, finding there was no likelihood of any other protection, applied to our workmen, convinced them of the criminality as well as imprudence of joining the mob, and kept them all at home, procured some arms, and had their promise of defending us and themselves against all invaders.

"Though our principles, which are well known, as friends to the established government, and enemies to republican principles, should have been our protection from a mob whose watchword was *Church and King*, yet our safety was principally owing to most of the dissenters living on the south of the town; for after the first moments they did not seem over nice in their discriminations of religion or principles. I, among others, was pointed out as a Presbyterian, though I never was in a meeting-house in Birmingham, and Mr. B. is well known as a Churchman. We had everything most portable packed up, fearing the worst; however, all is well with us. It must be observed to their credit, that they neither killed nor maltreated any of the sufferers, except such as opposed them by violence, among whom they dealt some civil knocks by bludgeons. Some military arrived on Sunday night, since which there has been no rioting in the town, and we hope they are dispersed."

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* 19th July, 1791.

Even three months later, when Dr. Priestley proposed paying a short visit to Birmingham for the purpose of taking leave of his friends and congregation there, Mr. Watt thought it necessary still to write to him recommending caution and delay. Afterwards, when the Doctor had removed, first to Clapton, and then to Northumberland in America, his friends "contributed," as he said, "to set up a broken philosopher" in his state of exile; and among the useful articles which in his new laboratory recalled the pleasant memories of Soho, were a digester, a chemical lamp, a number of duplicates from Mr. Boulton's collection of minerals, and what the worthy and venerable philosopher calls "the noble present of a furnace, and other apparatus for making large quantities of air;" which he found "invaluable," and much more convenient than anything he had ever possessed before.

In 1786, Mr. Watt and Mr. Boulton proceeded to Paris, on the invitation of the French Government, to meet proposals for their erecting steam-engines in that country under an exclusive privilege. In particular they were to suggest improvements on the great hydraulic machine of Marly; that gigantic specimen of a race of mechanical megalosaurians, now nearly extinct, of which Belidor has given a striking description, but which he introduces by the eulogy,—a very questionable one, as most of our readers know, where machinery is concerned,—"il ne paroît pas que l'on ait jamais exécuté de machine *qui ait fait autant de bruit* dans le monde que celle de Marly." *

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* Desaguliers, Annot. upon Lecture XII. of his 'Course of Experimental Philosophy.'

The Machine of Marly was erected at the village of that name upon the Seine, by Rennequin of Leige, for Louis XIV. in 1682, to raise water for the town and water-works of Versailles. This was effected by means of fourteen large water-wheels, and a series of pumps, pipes, cranks, and rods, remarkable for their complexity and the noise they made in working. The improvements suggested on this machine were not carried into effect; in consequence of financial difficulties, and the dismissal of the ministry. Since then a steam-engine has been erected by the French to do part of the work; and two of the wheels, with improved apparatus, are all that remain of this cumbersome machinery. It is amusing in the present state of hydraulic science, to read an account of the Machine of Marly, such as is given in Desaguliers:—"*When he*," says that writer, "*that comes to take a view of the engine at Marly, sees it cover a mile of ground in length, and the breadth greater than that of the whole river Seine,—he cannot but look upon it as a stupendous machine.* * * *It is said that the Machine at Marly cost above eighty millions of French livres, which is above four millons of pounds sterling. Some of the largest of our fire-engines, at present* [1744] *in use in England, will raise as much water to the same height, and not cost above ten thousand pounds.*"* The Marquis de Custine calls that ancient machine the same thing in mechanics, as of old the Inquisition in Spain was in politics;† "the venerable machine of Marly," says Mr. Watt, "they now consider as much the disgrace as it once was [considered to be] the honor of the nation:" and therein, also, let us hope that De Custine's parallel may now hold good.

This journey was not undertaken without proper precautions being used to prevent it being supposed that the manufacturers of the new steam-engines were desirous of pushing their own interests in any way that might prove prejudicial to their country; "I think," Mr. Watt wrote to Mr. Boulton, "if either of us go to France, we should first wait upon Mr. Pitt, and let him know our errand thither, that the tongue of slander may be silenced, all undue suspicion removed, and ourselves rendered more valuable in his eyes, because others desire to have us!" The principal objects of their visit were frustrated by the political circumstances of the time; and although "perfectly sensible of the honor which might be acquired by such a job as Marly," Mr. Watt was also fully aware that it would be attended with much labor and vexation, and he felt "by no means sure of the profit." But the English engineers had a very agreeable journey; and a most flattering reception in Paris from the ministry, who seemed much disposed to employ them in the line of their business, as engine-makers, in France. They however absolutely refused to engage in any such manufacture, as contrary to the interest of Great Britain. They had also the satisfaction of making the acquaintance of most of the eminent men of science of whom the great capital of France had then to boast, as Lavoisier, La Place, Monge, Berthollet, De Prony, Hassenfratz, Fourcroy, Delessert, and others; with most of whom they afterwards maintained a frequent and most friendly correspondence. Mr. Watt gaily described himself as having been on this occasion "drunk from morning till night with Burgundy and undeserved praise;" although greater temperance than his probably never partook of the entertainments which enlivened the scientific morning or evening, nor were the panegyrics of the great ever bestowed upon one who received them with more perfect modesty and self-distrust.

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* Desaguliers, Annot. on Lect. XII. of his 'Course of Experimental Philosophy.'

† 'L'Espagne sous Ferdinand VII.' Tom. ii. p. 67, ed. 1838.

It was then that Berthollet communicated to Mr. Watt his discovery of the new method of bleaching, by means of what was at that time termed the dephlogisticated acid of sea-salt; and exhibited the process in the presence of a number of spectators, among whom were Mr. Watt and Mr. Boulton. On their return to England, those gentlemen mentioned to Mr. Pitt that M. Berthollet was in possession of such a process, in the view of obtaining for him a parliamentary reward, or exclusive privilege in Great Britain;—an object, however, which proved to be so difficult of attainment, that M. Berthollet subsequently renounced any lucrative views connected with his discovery, in this country. He then gave permission to Mr. Watt to communicate it to his father-in-law, Mr. Macgregor, who was enabled to employ it in his trade, along with several new improvements of Mr. Watt's invention, the results of a long series of experiments. "In relation to the inventor," says Mr. Watt,* "he is a man of science, a member of the Academy of Sciences at Paris, and a physician, not very rich, a very modest and worthy man, and an excellent chemist. My sole motives in meddling with it were, to procure such reward as I could to a man of merit who had made an extensively useful discovery in the arts, and secondly, I had an immediate view to your interest; as to myself, I had no lucrative views whatsoever, it being a thing out of my way, which both my business and my health prevented me from pursuing further than it might serve for amusement when unfit for more serious business. Lately, by a letter from the inventor, he informs me that he gives up all intentions of pursuing it with lucrative views, as he says he will not compromise his quiet and happiness by engaging in business; in which, perhaps, he is right; but if the discovery has real merit, as I apprehend, he is certainly entitled to a generous reward, which I would wish, for the honor of Britain, to procure for him; but I much fear, in the way you state it, that nothing could be got worth his acceptance." The process was also practised on a large scale, (in consequence of similar information communicated to them by the original inventor,) by Messrs. Henry, and Messrs. Baker & Co., of Manchester; and so greatly did the new improvement succeed, that it soon aftewards appeared, on the occasion of a trial as to the validity of a patent for preparing the material used, that one bleacher at Manchester bleached at the rate of a thousand pieces of muslin (of thirty yards each) every day, and that the goods were only three days in hand until they were completely finished. Another declared that the saving of potash which he effected by using the new process, amounted to above 2000*l*. in the course of little more than a year.

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* To Mr. Macgregor, 27th April, 1787.

But we must turn from such *délassements* as scientific feasts and philosophical tours, by which the ordinary routine of Mr. Watt's laborious life was occasionally,—but only too seldom,—pleasantly diversified, to a far less agreeable but more compulsory occupation in which a considerable portion of it was now unavoidably consumed. For very many years, although seriously injured by the piratical practices of their opponents, they submitted to them, if not in silence, at least without openly punishing them by law. The consequence was, that in the course of time, engines on the principle of separate condensation, and with such other particulars of the Soho construction as could be picked up by bribery of workmen, and other clandestine means, began to be erected. It is true, that of such engines, which were of very erroneous proportions and defective manufacture, the performances were usually far from being successful. Some, like Hornblower's at Radstoke, were asthmatic, "obliged to stand still once every ten minutes, to snore and snort;"* "when they have got a very strong steam, it will make 21 strokes in three minutes, but then comes to rest, and must stand five minutes before it gets strength enough to make another stroke, and all the while they must fire away as hard as ever they can, otherwise it will not work at all." † Some were like Evans' mill, which was a gentlemanly mill: it would go when it had nothing to do, but refused to do any work." The greatest achievement which some others succeeded in effecting, was to burst their own boiler, or break their own machinery to pieces. But the manifestation even of such energy was rare among them; of all "the bodily presence,"—so, at least, thought Mr. Watt,—"was weak," and the work "contemptible." Still, even such imperfect and really useless machines injured the fair traders, by attracting customers through a specious though deceptive show of cheapness; while on the other hand, their numerous faults, and the annoyances which they caused, tended to excite a prejudice even against the Soho engines, which were often ignorantly classed along with them under the general category. At last, it was deemed right as the least of two evils, to try whether the exclusive privilege could not be compulsorily and penally established against those who had infringed it; and the wide field of litigation was therefore deliberately, though reluctantly, entered upon.

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* Mr. Watt to Mr. Boulton, 5th September, 1783.

† Mr. Watt to Mr. G. Hamilton, 22 September, 1782.

The legal proceedings, both in equity and at common law, which now became necessary, were numerous; and it is painful, even at this distance of time, to contemplate the mass of litigation through which, in mere self-defence, the patentees were compelled to struggle. A bill of costs, sent in by one firm of solicitors in London, for their outlay and professional services in matters connected with the various infringements, has been preserved, and is now before us: amounting, for the short space of the four last years of the time to which the extension of the patent was limited, viz., from 1796 to 1800, to between five and six thousand pounds! * This was unquestionably a fearful tax;—a burden grievous to be borne by the successful discoverer in science, and his enterprising associate, in seeking the final, though tardy, enforcement of justice!

The advancing years of both Mr. Watt and Mr. Boulton, of whom the expiration of the patent found the one approaching, and the other already past, his threescore and tenth year, made them both feel more sensibly the severity of so distasteful a conflict; which, although conducted with both skill and determination on their own part, was latterly intrusted chiefly to the management of their sons, Mr. James Watt, junr., and Mr. M. Robinson Boulton.

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* Long afterwards, (in 1818,) when speaking of an account, the charges in which were enormous, Mr. Watt said that "*it would not have disgraced a London solicitor.*" The experience of many of our readers may have taught them to understand the full force of this remark; although, happily, there are honourable exceptions to the too general rule.

"In the whole affair," writes Mr. Watt to his old friend, Dr. Black,[*] "nothing was so grateful to me as the zeal of our friends, and the activity of our young men, which were unremitting."

Two trials in particular there were, in which Mr. Watt's principal invention, and the patent granted for its exercise, became the subject of full and elaborate discussion; and which, both at that time and since, attracted too much attention to be at present unnoticed by us. Our remarks, however, on this part of our subject need be few, as further information on the various points noticed in the course of the arguments delivered, whether at the bar or from the bench, may be found in the reports of the opinions of the Judges, taken in short-hand at the time, and printed in a former work.[†]

In both of those causes Messrs. Boulton and Watt were the plaintiffs. The defendants were, in one of them, a person of the name of Bull; and, in the other, Messrs. [Jonathan] Hornblower and Maberly. "Mr. Bull was *a stoker*," and by having been employed by Boulton and Watt in that capacity, and afterwards as an assistant engine-tender, he gained that acquaintance with the construction of their engines, through which he ultimately sought to deprive them of their patent rights. The cause of "Boulton and Watt *v.* Bull," was tried in the Court of Common Pleas on the 22d of June, 1793, by a special jury, before Lord Chief Justice Eyre. Among the witnesses on the side of the plaintiffs were De Luc, Herschel, Lind, Southern, Mylne, Cumming, Murdock, More, Rennie, and Ramsden; and when their counsel rose to reply to the evidence adduced for the defence, the foreman of the jury said that the jury were already perfectly satisfied. The verdict was for the plaintiffs, subject to the opinion of the Court as to the validity of the patent. On the 16th of May, 1795, the special case came on for judgment; when the opinions of the Judges were equally divided. *For* the patent were Lord Chief Justice Eyre, and Mr. Justice Rooke; *against* it, Mr. Justice Heath, and Mr. Justice Buller. About the same time, so multifarious were the questions which the legal acumen of the counsel and Judges had raised concerning the patent and its infringement, that Mr. Watt writes, "Since I have been so much among the doubting limbs of the law, it is impossible to come to a conclusion upon any subject!"

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[*] 15 January, 1797.

[†] See the Appendix to the 'Mechanical Inventions of Watt,' Nos. V. and VII., vol. iii. pp. 164–207, and 252–292.

The cause of "Boulton and Watt *v.* Hornblower and Maberly," was tried in the Common Pleas on the 16th of December, 1796, and, like the previous case, by a special jury, before Lord Chief Justice Eyre. The verdict was, again, for the plaintiffs; and the proceedings on a writ of error subsequently brought, had only the effect of affirming that result by the unanimous opinion of the four Judges before whom it was argued, (as it was most ably and fully,) on two several occasions.

The arguments against the validity of the patent, offered by the defendants in the action, (the plaintiffs in error,) in the Common Pleas, were principally drawn from alleged objections to the sufficiency of the specification of 1769. And it must here be observed that the statute continuing the benefit of the letters patent, (which, having been granted for fourteen years from the 5th of January, 1769, would otherwise have been determined, by length of time, previous to the date of the action,) provided that every objection in law competent against the patent should be competent against the statute, in case the patent ought not to have been granted: on grounds, namely, of prior invention and public use, or of the specification not complying with the conditions required by the statute, (21 Jac. I., cap. iii.) But for such a proviso, objections to the validity of the patent, founded on the alleged insufficiency of the specification, could not have been listened to. It was, however, contended on the part of the infringers:—

1. Generally, that the description of the engine given in the specification was not sufficient to put the public in possession of the best mode of making such engines on the newly invented

principles, so as to entitle the patentee to the benefit of the monopoly, which the policy of the law prescribes shall be granted and secured only on condition of that being done.

How far this objection was or was not well founded, became, of course, matter of evidence for the jury; and while among the witnesses for the plaintiffs there was a unanimous concurrence of opinion as to the sufficiency of the description given in the specification, even those called by the defendants were, with few exceptions, also obliged to admit it. The exceptions were some three in number, and the contrary nature of their testimony was at once accounted for, either by the interest they had, as being themselves infringers, to overthrow the patent, or by their inferior skill in their business as mechanics.

A curious and interesting proof of how clearly the novel idea of condensation in a separate vessel could be presented to the mind of any one accustomed to consider mechanical subjects in a practical point of view, even when unaccompanied by anything like the fulness and clearness of the specification, was supplied by Mr. Robison in the following anecdote, which was understood at the time to have had a decisive effect on the minds of the Court and Jury:—

"In the year 1770," says Professor Robison, "I went to Russia, to take the direction of the Imperial Academy of Marine in that country. My house was adjoining to the bason into which the docks of Russia were drained; the water was drawn out by two expensive windmills; it occurred to me that a steam-engine would answer the purpose better; and, as that country was at a great distance from pit-coal, it occurred to me that Mr. Watt's engine was the best. I recommended the Admiralty College to erect a steam-engine; this occasioned a good deal of conversation between me and the gentlemen of science in that country, particularly a Mr. Model, the Court apothecary, a gentleman of great reputation, and one of the first chemists of the age, whom I had instructed in the doctrine of latent heat. I wrote to Mr. Watt, desiring him to undertake the erection of an engine. Mr. Watt, with that liberality which is natural to him, declined interfering in it. The expression of his letter was, 'I think you are fully able to conduct that project, and it will do you credit in the country where you are.' The day that I received this letter, I went to drink tea with Mr. Model; and found sitting with him Mr. Æpinus, a gentleman no less eminent for his beautiful theory of magnetism and electricity. I mentioned Mr. Watt's genteel declinature, and also a passage of his letter, in which he said that by admitting steam to press down the piston, its want of perfect tightness was not so hurtful as appeared at first sight, because the steam which got past would only be lost, but would not choke the engine. Model broke out into an exclamation, confirming what I said. Æpinus did not see the force of what we said, and Model took out his pencil to make a sketch which would explain it to him. Not readily finding a bit of paper, I pulled a bit out of my pocket, on which he made a sketch. This happened to be an official report, which I had that day received at Cronstadt, and which I kept with many things of this kind, and they came home with my other papers. I submit it to the inspection of the Court, and presume it will be acknowledged as a convincing proof that Mr. Model completely understood Boulton and Watt's method; and that much less information than is given in the specification is sufficient for enabling an intelligent engineer to erect an effective engine, or to comprehend Mr. Watt's principles."

2. It was objected, secondly, in particular, that the mode of condensation, (by injection of a jet of cold water,) was not specified.

But as this mode was familiarly known to all engineers, and even to most common mechanics, to have been ordinarily practised in Newcomen's engines, the repetition of it by Mr. Watt in his specification was quite uncalled for; no departure from the former practice, in that particular, being intended by him to be adopted.

3. That the relative proportions which the condenser should

bear to the cylinder, and which the air-pump should bear to the condenser, were not specified, so as to render it unnecessary to resort to experimental trials, in the construction of engines on the new principles.

On this head, it was readily shown that it was not requisite, according to any fair interpretation of the law, that the specification should describe the proportions of the various parts of an engine so that any person whatsoever might, without previous instruction as an engineer, be thereby enabled at once to construct a perfect steam-engine; that it was quite sufficient if it gave the information needful for such as had both received some previous education, and had some just right to be regarded as engineers; that the exact proportions of either the condenser or the air-pump were quite immaterial to the satisfactory performance of the engine, provided only they were large enough to do the usual work of condensation and pumping; and that the magnitude proper for each of them could not fail to be known to all who possessed the amount of previous knowledge required for such business before the new invention was made.

4. That of the various substances specified to be employed instead of water, to render the piston or other parts of the engines air and steam-tight, viz. "oils, wax, resinous bodies, fat of animals, quicksilver, and other metals in their fluid state," only one, (the fat of animals,) was useful and economical in practice; and quicksilver, in particular, by corrosion and amalgamation, would injure any parts of the engine that might happen to be made of brass, to which it might get access.

There was evidently nothing in this objection deserving notice; as it was pretty certain that if any one of the substances specified was both cheapest and best, (as was said to be the case with mutton suet,) *that* would soon be adopted, to the exclusion of the rest. As for the argument from the *quicksilver*, all mechanics at all acquainted with their business knew very well that that metal ought not to be applied to any brass work; and the Chief Justice could not help observing, that so *mercurial* an objection was scarcely to be considered as a subject for grave discussion.

5. That no annexed drawing or model of the new engine was lodged with the specification.

Unfortunately, the numerous piracies that were successfully practised, showed but too forcibly, that no drawing or model was requisite to enable counterfeits of the new engine to be made. The fact was, that either drawing or model was not only quite unnecessary, and, from the endless variety of forms in which the invention might be applied, quite useless; but it might really have injured the efficacy of the patent by limiting the extent of its application. For it must always be remembered, that the invention was not (as the infringers tried to represent it) of a new engine, but of a new method of saving fuel, by condensing the steam in a vessel apart from the cylinder. That separate condensation was the thing patented, in whatsoever form, or to whatsoever engine it might be applied; although the best mode of carrying out the principle, by valves, alternate communication, &c., was clearly pointed out, so as to be intelligible to all engineers or mechanics of ordinary capacity and education in their trade.

"I know," adds Professor Robison, "that it has been repeatedly objected to this opinion of men of science concerning the sufficiency of the specification, that Mr. Watt's own accounts are in opposition to it. He had to encounter many difficulties before he perfected his machine, even after obtaining his patent. I know this well. But this was chiefly in subordinate parts of the undertaking. I firmly believe that the great principles were as perfect in his mind in a few hours, as they are at this day; and that the physical parts of the problem were as completely solved by his first model, as they are now by his best engines. But when Mr. Watt was engaged in bringing the contrivance to perfection, he wished to perfect every part. He who wished to make his engine not only the best, but the cheapest in the world,—he struggled long, in opposition to his own judgment, at Dr. Roebuck's instance, to perform the condensation without injection. He had a predilection for the wheel engine, and much time and labour were spent on it, while he was uncertain whether he should bring this, or the reciprocating engine, first to the market. He had experience to acquire in great works, and in the practice of several trades employed in such constructions. He had workmen to instruct, and to form; and to keep with him, after they had acquired from him a little knowledge, and were worth bribing away from him. But the chief cause of the delay was that indelible trait in Mr. Watt's character, that every new thing that came into his hands became a subject of serious and systematic study, and terminated in some branch of science. How rarely do we meet with such a conjunction of science and art,—how precious when it is found;—how much then does it deserve to be cherished! What advantages have been derived within these twenty years from this fortunate union;—how much then does it become our courts to encourage and support it against the unprincipled attacks of ignorant and greedy plagiarists, who would deceive our men of property, ruin them by expensive projects which terminate in disappointment, and thus discourage those who alone can by their capital give any effectual aid to the energy and genius of this country! We boast of our Newton, and place him at the head of our philosophers;—our Boulton and Watt want only *justice*, and all Europe will place them at the head of our artists."

The originality of the invention, and its great importance to the public, were at once established by the plaintiffs; and, indeed, were admitted by the defendants. The very multitude of the infringers bore testimony to the value of the discovery; their occasional construction of tolerable engines on the new principle, proved the sufficiency of the specification; and their audacity was in proportion to the despair they felt of being able to rival, by honest means, the success of the inventor. The whole weight of the evidence was justly held to be in favour of the plaintiffs, on whose side were called men of the highest order of intelligence and of the greatest celebrity in physical science, as well as in the various departments of the arts:—such as De Luc, Herschel, Ramsden, Robison, Cumming, Southern, and others, most of whom, as has already been mentioned, had also given evidence in the previous case against Bull.

Among the host of opponents who, having in the first place themselves infringed the patent, were *disinterestedly* desirous, *for the benefit of the public*, that its validity should be overthrown, one of the most forward, pertinacious, and loud, was Joseph Bramah. This person, very well known for his ingenuity in mechanical improvements in locks, his hydraulic press, and other useful contrivances, attended as a witness on behalf of the defendants in 1796; but having on that occasion been cut short, by the Judge, in an endeavour to lay before the Court what he calls "a few remarks,"—(they extend to ninety-one printed pages!),—he at last delivered them to the public in the form of a letter to the Chief Justice, remonstrating against the verdict which had been unhesitatingly found for the plaintiffs. In the outset of this epistle, Bramah states that he was, at the trial, "much incapacitated by those alkalescent and morbific exhalations, ever a consequence of large and close assemblies;" and the abrupt judicial syncope of his intended evidence he attributes, (no doubt justly enough,) to the attention of the Court having "become flaccid through fatigue."

The specification of the separate condenser generally, is, this excelling sage informs us, a "very abstruse and ambiguous concern:" and that of the steam-wheel, "a complete jumble of incoherent, unconnected, absurd, and indigested ideas; so blended *and coagulated with mystery*, ambiguity, and impossibility in practice, that it is a disgrace to the writer, and would undoubtedly *ruin any mechanic who might attempt to analyse it*."

The principle of working engines by the alternate expansion and contraction of steam, (the expansive principle added to the separate condensation,) he introduces thus:—"And behold! what does he," [Mr. Watt] ("by way of misleading) but propose what every man of chemical science must reject, viz., to work engines by the partial expansion and condensation of steam!"

Bramah offers it as "a condensation of his own ideas diffused through his letters," that "*all kinds of condensers*, and even eduction-pipes, on the principle of Watt's engines, *impede the working of the engine;*"—and "thinks that it must be obvious to every one, *as it had ever been to him, that Mr. Watt had really invented nothing but what would do more mischief than good to the public.*"

It was in the vexation caused by the multifarious piracies, of which Bramah's was one, that Mr. Watt was tempted, "in the anguish of his mind," almost to "curse his inventions;"—to declare that "there is nothing more foolish than inventing;"—and that "nine-tenths of mankind are knaves, and a large proportion of the remaining one-tenth, fools." From an equally temporary cause alone, let us hope, also proceeded his evil opinion of some of the gentlemen belonging to a certain branch of the legal profession, whom he called "the anthropophagi of London;" and of whom he said, that "if all the counties in England would join in petitioning Parliament to make it high treason for any of the tribe to be found in the realm, it would be the wisest thing they ever did!"* It was certainly unfortunate for the reputation of Bramah, himself a self-taught inventor of great mechanical ingenuity, that he should have been led, by whatever motive, into systematic and grudging opposition,—(which was also, happily, unsuccessful,)—to the grand and prolific discoveries of Watt.

The verdict of the jury, on occasion of both of the trials, having gone with the stream of testimony which flowed so overwhelmingly in favour of the patentees, the judgment of the Court finally established the legal validity of the letters patent, and effectually vindicated the justice of all the claims that Boulton and Watt had made. That decision has always been viewed as one of great importance to the law of patents in this kingdom, and was, of course, productive of momentous consequences in a pecuniary point of view to the patentees; as, besides heavy damages and costs being recovered from the actual defendants, the remainder of the horde of delinquents were thereby, at last, awed into subjection, and compelled to disgorge a large portion of their illegal gains. In judgment on the vanquished, however, mercy was not forgotten by the victors; and the terms of settlement insisted on were, it is believed, generally satisfactory to all parties. Mr. Watt used, long afterwards, to call the specifications his old *and well-tried* friends.

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* To Mr. Boulton, 12 April, 1780.

CHAPTER XXIV.

TERMINATION OF THE PATENT-PRIVILEGE OF 1769 AND 1775—AND OF THE ORIGINAL PARTNERSHIP OF BOULTON AND WATT—CONTINUANCE AND INCREASE OF THEIR STEAM-ENGINE BUSINESS—ATTEMPTED ROBBERY—ASSISTANTS AT SOHO—WILLIAM MURDOCK, HIS LIFE, SERVICES, AND INVENTIONS—MR. WATT IN HIS OLD AGE—PNEUMATIC MEDICINES—FOUNDATION OF PRIZE IN GLASGOW COLLEGE—LIBRARY AT GREENOCK—CHARITABLE ACTS.

WITH the year 1800 came the expiration of the privilege of the patent of 1769, as extended by the statute of 1775; and also the dissolution of the orignal copartnership of Messrs. Boulton and Watt, of five-and-twenty years' duration; a term which had been fixed with a prospective reference to the duration of the privilege, and which, having at its commencement found the partners active and strong,

> "In mezzo del cammin' di nostra vita,"

left them, at its close, far advanced on that toilsome journey, and disposed to resign the cares and fatigues of business to other and younger hands. Those two friendly associates, who might well be termed the fathers of the modern steam-engine, did not, therefore, in their own persons renew the contract which they had in earlier and more eventful times so strenuously, so successfully, and so happily fulfilled. But their respective shares in the concern were readily adopted, as the basis of a new contract, by their sons, Messrs. James Watt, jun., Matthew Robinson Boulton, and Gregory Watt; all distinguished by great talents, and already to a considerable extent initiated in the conduct of the business, by those valuable instructions which the experience of their fathers had so well enabled them to give; as well as by having held, from 1794, some individual interest in the property of the copartnership.

The new partners then entered on a course of enterprising management, from which one of their number, Gregory Watt, was too soon removed by his premature death in 1804. This lamented person, having never felt much interest in the dry details of business, had been by the kindness of his elder brother, James, in great measure relieved from them, and enabled to devote his mind solely to those higher pursuits of science and literature in which he found delight; retaining at the same time the independent circumstances and command of leisure which his share of the profits from the steam-engine manufactory enabled him to enjoy. In the case of the other two gentlemen, the business connection endured without any material alteration for a period of no fewer than forty years. And it is a remarkable fact, demonstrative alike of the continual advance in the development of the various resources of this country, and of the energetic ability with which the affairs of the Soho manufactory were conducted, that, notwithstanding the cessation of the exclusive privilege, and the immense competition in the construction of steam-engines which speedily followed, so far was the business of Boulton and Watt from diminishing, that it continually increased, and became greatly more profitable than it ever had been in the days of its original founders. Even after all of his manifold improvements had been secured by patent, and were in course of execution in the various engines turned out from the Soho manufactory, Mr. Watt had made a very moderate estimate of the remunerative nature of the business;—for although in the summer of 1782 he mentioned that the clear income realised by it was 3000*l.* per annum, and might be 5000*l.*, he at the same time added that it might be less, or nothing; depending on how far Mr. Boulton and he might be able to defeat their opponents. "From the many opponents we are like to have," he also wrote to Mr. Boulton,* "I fear that the engine business cannot be a permanent one; and I am sure it will not in any case prove so lucrative as you have flattered yourself;"—and "I will stick by the engine business while it sticks to me; but we have got so many pretenders now, that I fear they will make us little people. If so, let them." * "I do not think that we are safe a day to an end in this enterprising age. One's thoughts seem to be stolen before one speaks them. It looks as if Nature had taken an aversion to monopolies, and put the same thing into several people's heads at once, to prevent them; and I begin to fear,"—he very unreasonably went on to say,—"that she has given over inspiring me, as it is with the utmost difficulty I can hatch anything new." †

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* 20th February, 1782.

But, towards the close of the last century, and on the favourable termination of the long lawsuits, the business became so profitable as fully to satisfy the moderate desires of Mr. Watt; to provide an obvious source of independent income for his sons; and thus to remove the fears which had often pressed heavily on his mind, that he might possibly outlive its success.

At the very beginning of the century, viz., on Christmas eve, 1800, a great robbery was attempted at Mr. Boulton's silver-plate manufactory; a building which adjoined the engine-yards and workshops, and was at no great distance from his mansion-house.

The robbery need scarcely have been mentioned here, but for the accidental circumstance of it having become known to Sir Walter Scott, and having furnished him with an incident of great pictorial effect in one of his most romantic scenes, that, viz., in 'Guy Mannering,' between Meg Merrilies and Dirk Hatteraick in the cavern. Sir Walter's graphic description of the robbery is given in Allan Cunningham's Memoranda, published in Lockhart's 'Life of Scott.' ‡ "I like Boulton," continued Sir Walter; "he is a brave man, and who can dislike the brave? He showed this on a remarkable occasion. He had engaged to coin for some foreign prince a large quantity of gold. This was found out by some

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* 22nd May, 1782.

† To Mr. Boulton, 14th February, 1782.

‡ Chap. liii.

desperadoes, who resolved to rob the premises, and, as a preliminary step, tried to bribe the porter. The porter was an honest fellow,—he told Boulton that he was offered a hundred pounds to be blind and deaf next night. 'Take the money,' was the answer, 'and I shall protect the place.' Midnight came,—the gates opened as if by magic,—the interior doors, secured with patent locks, opened as of their own accord,—and three men with dark lanterns entered and went straight to the gold. Boulton had prepared some flax steeped in turpentine,—he dropt fire upon it, a sudden light filled all the place, and with his assistants he rushed forward on the robbers;—the leader saw in a moment he was betrayed, turned on the porter, and shooting him dead, burst through all obstruction, and with an ingot of gold in his hand, scaled the wall and escaped." "'That is quite a romance in robbing,' I said; and I had nearly said more, for the cavern scene and death of Meg Merrilies rose in my mind."

Sir Walter, although quite correct as to the main feature of the illumination of the scene of plunder and rescue, was slightly inaccurate in one particular; for the porter, or watchman, although shot in the neck, recovered and lived long afterwards on a pension, which was the reward of his fidelity to his employer. He was, however, removed from the neighbourhood of Birmingham, to be safe from the threatened resentment of other members of the same lawless gang which had been so largely decimated; and so strictly was his incognito obliged to be preserved, that we have heard that his place of concealment was not communicated even to his wife:—a strong measure of domestic economy to which he must of course have been a consenting party. For three nights previously, the robbers had tried keys and examined the premises, "which, by our wise law," says Mr. Watt, "is no felony; and, had we apprehended them, they would soon have been let loose upon the public, and we could not have rested in safety. We were, therefore, obliged to let them commit the robbery; and, on their coming out, fell upon them with guns, pistols, bayonets, and cutlasses. * * Our young men were commanders-in-chief, and laid their plans very well; but one of our guards came not soon enough to their station, by which the escape took place, though by a way deemed impracticable." Four of the thieves were taken. The fifth member of the marauding party was, as we learn from the proclamation of reward issued at the time, as well as from another part of Mr. Watt's letter just quoted, surnamed the "Little Devil," and had come from Manchester expressly to join what we may call the shooting-party; he broke his arm, and was otherwise badly wounded and bleeding from his fall; but, although some slugs had passed through his hat, he was uninjured by shot. He was not apprehended for four or five months afterwards. All the five prisoners were tried at the next assizes at Stafford, and the four first secured were sentenced to death; "the Little Devil" was sentenced to be transported for seven years, possibly from having borne no active part in the murderous affray, and also, perhaps, in consideration of the suffering he had already undergone. In regard to the others, a point of law, as to how far the plate manufactory, which was within Mr. Boulton's grounds at Soho, but of course apart from his residence, came within the definition of a dwelling-house, and consequently, how far the offence committed was or was not a burglary, was reserved for the opinion of all the Judges; and we rather believe that the capital sentence was ultimately not carried out on any of the culprits.

We need scarcely observe, that during the last half-century the Soho works have been one of the principal sources,—(for a great portion of the time, indeed, *the* principal source,)—of that vast supply of steam-power which the inventions of Watt have enabled this and other countries to obtain. At the public meeting in London on the 18th of June, 1824, at which a monument to Mr. Watt in Westminster Abbey was voted, the amount of power which had been thus created at Soho was stated by the late Mr. Boulton to be, in round numbers, eqivalent to that of one hundred thousand horses; and since that time, up to 1854, an addition of nearly two-thirds of that amount had been made; giving a total sum of power equivalent to that of about one hundred and seventy thousand horses. We subjoin a return of the particulars, prepared from the most authentic records; and as upwards of seven hundred men have been kept in full employment at the great establishment to which we refer, there seems no reason to apprehend any diminution in the future extent of its usefulness and prosperity.

"MEMORANDUM—SOHO FOUNDRY, 16 *March*, 1854.

"The number and power of the engines made by Messrs. Boulton, Watt, and Co., to the date January, 1824, were thus reckoned by the late Mr. Boulton and Mr. Creighton, (one of his assistants at Soho):—

	Engines.	Nominal horse-power.		Power of living horses required to do the same work.
283	for pumping and blowing .	11,247	× 4 =	44,988
805	rotative	12,618	× 3 =	37,854
76	boat engines	2,080	× 3 =	6,240
1,164		25,945		89,082

"And between January, 1824, and January, 1854, the numbers are the following:—

34	for pumping and blowing .	2,403	× 4 =	9,612
164	rotative	7,517	× 3 =	22,551
243	boat engines	15,358	× 3 =	46,074
441		25,278		78,237

"Giving the following total numbers:—

1,164	25,945	89,082
441	25,278	78,237
1,605	51,223	167,319

"The first engine seems to have been made for Bedworth in 1776."

For the information of those of our readers who are not familiar with the reason of the difference between the nominal horse-power, and what may be called the real or effective horse-power of an engine, it may be mentioned, that an engine of a given number of nominal horse-power can, during a certain time, as *e. g.* from one to six hours, do the same amount of work as could be done by a like number of horses in the same time. But it can do more than this; for a living horse can, on an average, work effectively, day after day, only for about six hours out of the twenty-four, whereas the steam-engine can work for all the twenty-four hours. In order to ascertain the number of living horses, and therefore the *real* horse-power that would be required to do the same amount of work that is done by an engine of a given number of *nominal* horse-power, the nominal horse-power must be multiplied by four.

This, accordingly, is done in calculations of the effective power of pumping and blowing engines, where the application of the steam-power is *direct*. But in rotative engines, whether on land or for boats, there is estimated to be a loss of power in the action by the crank, &c., as compared with the direct application in the other case, which is allowed for by multiplying the nominal power only by three.

For the same reason, doubtless, it is that the horse-power in pumping and blowing-engines has always been calculated with an effective pressure of 9⅓ lbs. on each square inch of the piston, while in rotative engines it is only taken at a reduced effective pressure of 7 lbs.; these numbers being to each other in the same proportion as four to three, or 3 : 4 : : 7 : 9⅓. We are informed, on excellent authority, that "this mode of calculation is that which was adopted by *the original Watt*, and is still followed at the Soho works."

The continued success of the Soho steam-engine works, and the high character of all their manufactures, were unquestionably owing not only to the commanding talents of those who presided over them, but also to the abilities of various excellent assistants: such as were Southern, the two Creightons, P. Ewart, and Lawson, all of whom, in various responsible capacities, rendered energetic and valuable service.* But the foremost place in that honourable rank we must assign to William Murdock, for upwards of half a century Mr. Watt's most able, faithful, and esteemed assistant; who, both in his intellectual endowments, and in the manly independence of his mind, possessed no inconsiderable resemblance to his revered master and friend.

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* We may say the same of Messrs. Gilbert Hamilton and James Brown, to each of whom, in acknowledgment of their great and long-tried skill in conducting that extensive business, the late Mr. Watt, of Aston Hall, bequeathed a considerable share in the capital stock of the present copartnership of James Watt and Co. He no doubt felt satisfied that he could not take a more effectual method of insuring prosperity to the great manufacturing association, the interests of which he had so much at heart.

Born in 1754, at Bellow Mill near Old Cumnock in Ayrshire, Mr. Murdock early manifested the most decided predilection for mechanical pursuits; and after qualifying himself for their prosecution chiefly by his own unaided industry, he offered himself to Messrs. Boulton and Watt in 1776, or 1777, and was at once employed by them at Soho in superintending the construction and erection of their engines. He was soon sent into Cornwall as the agent of the firm, where, after vigorously contending with many difficulties, he ultimately succeeded in giving great satisfaction to the mining interest, as well as to his own masters; and he was afterwards employed for nearly twenty years at Soho foundry.

M. Charles Dupin, in an interesting account which he has published* of the great meeting in 1824, for the purpose of voting a monument to Watt in Westminster Abbey,—says:—"There was to be remarked among the spectators a venerable old man, whose intrepid services I could have wished had also been rewarded by some flattering marks of public gratitude. Mr. Murdock directed the application of the new steam-engines, to drain the water of the Cornish mines. In order to adapt that moving power to exhausting-pumps, and to establish the system in mines of extreme depth, inundated by appalling quantities of water, great skill in practical mechanics was requisite. Mr. Murdock showed that he was full of all the resources of genius, and the wisdom of experience, so as to triumph over every difficulty. Scarcely had those obstacles been surmounted, than the proprietors of the mines sought to deprive Messrs. Watt and Boulton of the benefit of the agreement into which they had mutually entered. But the incorruptible Murdock showed himself insensible to every temptation; he long withstood all menaces, and retired only when he saw the cupidity of the men whose frauds he defeated, threatening to destroy him in the mines by throwing him down their pits." Of this last anecdote of M. Dupin we have heard, from the late Mr. Watt, another version, which is somewhat different, and, for many reasons, more likely to be correct;—viz., that some of the "captains" of the Cornish mines, on occasion of a meeting of several of their number with Murdock on business connected with the engines, having attempted to *bully* him, he quietly locked the door of the room in which they were assembled, stripped, and, making a dexterous use of those arms with which nature had supplied him, administered to more than one of their number a lesson of persuasive efficacy, such as they would never forget, and such as he was never called on to repeat. He was, in truth, of Herculean proportions, and in muscular power nearly unrivalled.

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* 'Discours et Leçons sur l'Industrie, le Commerce, la Marine, et sur les Sciences appliquées aux Arts,' tom. i. p. 202, 1825.

M. Dupin adds, that he could have wished to have seen Watt, who was so pre-eminent in the art of discovering and attracting to himself men endowed with rare talent, recompensing the skill, the energy, and the integrity of Mr. Murdock, by assuming him as a partner along with Mr. Boulton, in their grand and rich enterprise. But here also we have it in our power to dispel the anxiety which M. Dupin thus again,—perhaps somewhat needlessly,—felt it incumbent on him to manifest on behalf of Mr. Murdock. For although never formally assumed as a partner in the Soho concern, and, therefore, remaining always exempt from all chance of loss in case of that business at any time failing of success, he always received a liberal income from his employers; and from 1810 to 1830, he was placed *on the footing of a partner*, without having to advance a shilling of capital to the partnership funds, without the risk of incurring any liability, and with a fixed salary of 1000*l.* per annum, assigned to him in lieu of a share of the fluctuating profits. From 1830, he lived in peaceful retirement in the neighbourhood of those works to which his energies had been successfully devoted, until his death, which occurred in 1839. His remains are deposited in Handsworth church, near those of Mr. Boulton and Mr. Watt; where "a bust by Chantrey serves to perpetuate the remembrance of his manly and intelligent features," and of the mind of which they were a pleasing index. There is also a fine portrait of Mr. Murdock in the hall of the Royal Society of Edinburgh, of which he was a Fellow.

On the subject of the economical employment of gas-light from coal, his systematic experiments commenced in 1792. For his paper on that subject presented to the Royal Society in 1808, which was read by Sir Joseph Banks, and printed in the 'Philosophical Transactions' for that year, (pp. 124-132,) he received the large Rumford gold medal; and he will ever be known as the true inventor of the beautiful system of lighting by gas. "The original inventor of this application of the gases," says Mr. Watt in 1809, "is Mr. William Murdock, a most ingenious man, now at Soho here, under whose directions several very large manufactories have been lighted, at Manchester and elsewhere, by Boulton, Watt, and Company. Mr. M.'s invention is of fifteen or twenty years standing. I saw it employed at Soho in the fireworks for the celebration of the last peace." While Mr. Murdock's improvements on this subject were in progress, Mr. Watt happening to hear a lady express admiration of the introduction of water by pipes into all the dwelling-houses of a large city, remarked that he hoped it would not be long before she would see fire and light introduced in the same manner; a prediction which then sounded strange enough, and yet was literally fulfilled. But that is by no means the only useful discovery with which Mr. Murdock's name is associated. He secured by patent, in 1799, "certain new methods of constructing steam-engines;" and, in 1810, "an improved method for boring pipes, cylinders, and circular disks, out of solid blocks and slabs of stone of any kind or description." In 1809 he made known, (not securing it by a patent,) a new method of refining porter, &c., without the aid of isinglass, then, as now, a most expensive material; and for this he received a substantial and handsome reward from the brewers of the metropolis. The working-model of the steam-carriage of 1784* shows how aptly he carried out the designs contained in the specifications of Mr. Watt: and the oscillating cylinder† is only one of very numerous and valuable suggestions with which he enriched the Soho machinery.

Although the commencement of the new era in the history of Soho found Mr. Watt already past what is commonly called the grand climacteric of man's life, he happily long lived to witness the continued stability and immense progressive increase of his business, in the hands of those dear to himself. His health had never, from his childhood, been robust; and it still was variable; but it had strengthened as his age advanced, and had never, perhaps, been worse than what one of his engineering friends called "a sort of counterpoise to prosperity, success, or happiness,—or, to speak more in our own way, a kind of fly-wheels to the machinery;"‡ the fatigue of those very exertions which his laborous life had rendered compulsory seeming to have fortified rather than to have enfeebled his frame. His spirits also became naturally more equable, as the principal causes of his anxiety and occasional depression were removed; and, while he was destined to be one of those "so strong that they come to fourscore years," his strength even then, as it could scarcely be termed "labour," was certainly very far from "sorrow." The period, indeed, which commenced with the new century, and brought him a release from active business, was a serene and golden time; in which, peacefully reposing from the honourable toil of his earlier days, he found a calm and constant satisfaction in their retrospect; and those hours of happy leisure were no less delightful to himself than instructive to the "troops of friends" who, in common with all that can add dignity or cheerfulness to old age, were gathered around him.

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* See the 'Mechanical Inventions of Watt,' vol. iii. plate XXIX.: and p. 450, *infra*.

† Ibid. plate XXXIV.

‡ Mr. Telford to Mr. Watt, 17 December, 1801.

A wide range of subjects of a scientific and useful nature continued to attract the notice of his inquiring mind. Among other pursuits, he had been induced, by the sorrow he experienced in losing his daughter, who died of consumption at an early age, "to step," as he expressed it, "over the bounds of his profession," and to communicate to Dr. Beddoes the ideas he entertained on the employment of "pneumatic medicines." It appeared to him that if poisons could be carried into the system of the lungs, remedies might be thrown in by the same channel; and that, although there seemed to be objections to the introduction, in that way, of powders, such as of Peruvian bark, &c., however finely they might be *mechanically* divided, yet that if the virtues of such substances could be obtained by solution or suspension in air of some species, they might have their full effect when inhaled and respired. With the view of aiding medical practitioners, as well as private patients, in their experiments and researches on this subject, he contrived a convenient apparatus for the preparation and inhalation of the various airs, which was extensively manufactured for sale at Soho. He also in many ways greatly aided Dr. Beddoes in his establishment of the Pneumatic Institution at Clifton, near Bristol: an establishment famous for having early profited by the services, and developed the chemical talents, of Humphry Davy. The system from which Beddoes hoped so much, although it has never yet realised his large expectations, seemed at first to produce some remarkable results; and it is impossible to despise the importance of facts, or to overlook the ingenuity of deductions which were contributed by men such as Beddoes, Jenner, Edgeworth, Humphry Davy, and Watt, and which led all of them to expect effects of an extensively sanative and beneficial character.*

It was always a favourite wish of Mr. Watt's heart to promote the attainment by others of that spirit of industrious research and invention by which he had himself been so entirely governed; and the following is a letter by which he founded, in 1808, a prize in Glasgow College, as some acknowledgment on his part of "the many favours" that learned body had conferred upon him, and of his sense of the importance of promoting the special study of the sciences of natural philosophy and chemistry. It is addressed to the Rev. Dr. William Taylor, the Principal.

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* See the 'Considerations on the Use of Factitious Airs, and on the Manner of obtaining them in large Quantities,' &c., by Dr. Beddoes and Mr. Watt, published at Bristol in 1794, 1795, and 1796.

"Heathfield, Birmingham, June 3rd, 1808.

"Reverend Sir,—I take the liberty of requesting you, in your official capacity, to communicate the following proposition to the Faculty of your University, and, on my part, to request their favourable acceptance of it.

"Entertaining a due sense of the many favours conferred upon me by the University of Glasgow, I wish to leave them some memorial of my gratitude, and, at the same time, to excite a spirit of inquiry and exertion among the students of Natural Philosophy and Chemistry attending the College; which appears to me the more useful, as the very existence of Britain, as a nation, seems to me, in great measure, to depend upon her exertions in science and in the arts. I therefore propose to settle 300*l.* upon the College, in Trust, to be laid out at the best interest, upon landed security, 10*l.* of which to be given annually as a premium for the best essay on some subject in one of the branches of Natural Philosophy hereinafter mentioned, which shall be appointed by a majority of the Principal, Professors, and Lecturers of the University, and which shall be composed by any *actual* student of the University who shall have gone through a regular course of Languages and Philosophy, either at Glasgow or in any other Scottish University. The prize to be adjudged by the majority above mentioned, in conjunction with Gilbert Hamilton, Esq., my brother-in-law, so long as he shall live; and [it] shall be subjected to the same rules and regulations, as to the time and manner of giving it in, as the other prize-essays appointed by the University. If in any year no essay shall be judged worthy of the prize, the same subject shall be re-appointed for the following year, and the premium reserved for it, to be adjudged at the same time with the premium for such other subject as shall be regularly appointed for such year; and if then no adequate essay shall appear, the said premium to be added to the principal sum.

"I know not whether the interest will be subject to the property-tax; but, in any case, the surplus, whatever it may be, after paying the premiums, and 10*s*. 6*d*. to the clerk of the meeting, is to be added to the principal annuity; until it shall accumulate so that the interest shall be able to afford two premiums on two subjects, to be appointed as aforesaid.

"I had at first intended that the subjects for the prize-essay should be taken from any branch of Natural Philosophy or Chemistry; and now think it proper to restrict them to the following branches, and in the following rotation:—

"First Year, to any branch of Mechanics, or its dependent Arts.

"Second Year, to Statics, and the Machines and Arts dependent.

"Third Year, to Pneumatics, Statical or Chemical Machines and Arts.

"Fourth Year, to Hydraulics, Hydrostatics, their Machines and Arts.

"Fifth Year, to Chemistry, its Arts and Apparatus.

"The Sixth Year, the rotation to begin with Mechanics, as before, and so on by five years' rotations.

"I should request a copy of the successful essay to be sent me annually, and, after my decease, to my male representative; and I request that no public mention may be made of this donation, by paragraphs in the newspapers, or otherwise, until a prize come to be adjudged; [I] not being, as far as I know, actuated by vanity, but by a desire to stimulate others to do as I have done.

"I reserve to myself, at any time during my life, by any writing under my hand, to change either the rotation or the subjects of the essays, as well as the other regulations concerning them.

"Should what I now propose meet the approbation of the Faculty, I shall immediately direct a proper deed to be drawn, and the money to be paid to their order.

"Requesting you, Sir, to accept my most respectful compliments, and to present them to all the other members of the Faculty, I have the honor to remain, Reverend Sir, your most obliged, and most obedient humble servant, JAMES WATT."

Some years later, also, (in 1816,) he made a donation to the town of Greenock, for the purpose of purchasing scientific books for the use of the mathematical school of the place, under the care and guardianship of the magistrates and town-council: his intention being "to form the beginning of a scientific library for the instruction of the youth of Greenock, in the hope of prompting others to add to it, and of rendering his townsmen as eminent for their knowledge as they are for their spirit of enterprise." This design carried out (as he wished) by his townsmen, with the munificent aid of his son, the late Mr. James Watt, has been at last completed; and a large and handsome building, containing the library and a beautiful memorial statue of its founder, by Chantrey, is now a principal ornament of that busy and prosperous seaport, which boasts that James Watt was born in her.

Nor, amid such donations, given as aids to the promotion of sound and useful learning, were others wanting on his part, such as true religion prescribes, to console the poor and relieve the suffering. But those his benefactions, which were also secret, being usually accompanied at the time by an injunction not to make known the name of the donor, we shall not here seek farther to disclose; preferring to dwell on the comfortable truth, that "there be some persons that will not receive a reward for that for which God accounts Himself a debtor: persons that dare trust God with their charity, and without a witness." *

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* Izaak Walton, 'Life of Dr. John Donne,' p. 54, ed. Oxford, 1824.

CHAPTER XXV.

STEAM-NAVIGATION—ITS ORIGIN AND PROGRESS—PADDLE-WHEELS—EARLY STEAM-BOATS—PAPIN, HULLS, MILLER, SYMINGTON, FULTON, HENRY BELL, ETC.—MR. JAMES WATT, JUNIOR—HIS VOYAGE IN THE "CALEDONIA," IN 1817, TO GERMANY, BELGIUM, AND HOLLAND—H. M. S. THE "JAMES WATT"—LOCOMOTIVE STEAM-CARRIAGES—MR. WATT'S PATENT, AND MR. MURDOCK'S MODEL, OF 1784—MR. WATT'S VIEWS OF LOCOMOTION ON LAND BY STEAM.

A SUBJECT which naturally excited a deep, and, indeed, at one time, rather an anxious interest in the breast of the great engineer, when resting in his latter days from the severer labours of his life, was that of steam-navigation. With every confidence in the probable success of such a system, he seems never in any very especial manner to have directed the force of his own mind to the details requisite for carrying it out; a circumstance which is quite explained by the constant demands on his time and attention made by other branches of the steam-engine business, so long as he continued to be actively engaged in its prosecution.

The mere use of paddle-wheels, "remi rotatiles," or "rames tournantes," moved by animal force, for the progression of boats, appears to have been of considerable antiquity. Not to carry our inquiries further back, they have been fully described by Valturius, in his great work on the 'Science of War,' in 1472; by William Bourne, in 1578; by Denis Papin, (as having been seen by him in use in England, probably in 1682,) in 1690; by

Savery, in 1698; by Du Quet, in 1702 and 1735; by the Comte de Saxe, in 1732, &c. Papin, also, in 1690, unquestionably suggested the employment of *the atmosphere* as a power, with a vacuum formed by the condensation of steam beneath a piston in a cylinder, the power being communicated by toothed and paddle-wheels "ad naves adverso vento provehendas." Since the days of Papin, indeed, the experience of a century and a half has fully enabled us to judge how great was the distance between the imperfect conception of a project, such as he suggested in the passage quoted above, and its successful consummation.

It still, curiously enough, remains uncertain whether Jonathan Hulls carried into effect the more elaborate invention for which he obtained a patent in 1736, and which he set forth in his celebrated pamphlet entitled 'A Description and Draught of a new-invented Machine for carrying Vessels or Ships out of or into any Harbour, Port, or River, against Wind and Tide, or in a Calm:' London, 1737. But he has, at least, minutely described the introduction of a Newcomen's engine into a large boat or barge to be employed as a tug, and has delineated such a vessel, fitted with fan (or paddle) wheels, towing a ship of war of upwards of thirty guns.

After the date of Mr. Watt's patent of 1769, (the great pivot on which all real advancement in the steam-machinery of modern times has turned,) it is said that, in the United States, Mr. Ellicot, in 1775, and T. Paine, (less favourably known by his writings,) in 1778, suggested the use of steam for propelling boats; as the Abbé Arnal did in France in 1781, for inland navigation; while in 1782 the Marquis Jouffroy built a steam-boat, which was tried on the Saône, but did not succeed. In 1783, Mr. James Rumsey of Virginia and Mr. John Fitch of Philadelphia both proposed methods of propelling boats, the one by a current of water forced out at the stern, and the other by paddles, but not in the form of wheels. It is said that Mr. Fitch constructed a steam-boat which was navigated between Bordentown and Philadelphia, but was soon laid aside.

In 1787, Mr. Miller of Dalswinton published a description, with engravings, of a triple vessel, propelled by paddle-wheels, turned by means of cranks, intended to be worked by men; adding, "I have also reason to believe that the power of the steam-engine may be applied to work the wheels, so as to give them a quicker motion, and, consequently, to increase that of the ship." In 1788, Mr. Miller employed Mr. William Symington, of Wanlockhead, in Dumfries-shire, along with Mr. James Taylor, to superintend the construction of a small steam-engine in a pleasure-boat on Dalswinton Loch. This succeeding well, induced him to employ Mr. Symington to construct a larger steam-engine at Carron, for one of Mr. Miller's boats on the Forth and Clyde Canal, which was tried in 1789, and a speed of about seven miles an hour attained; but from other objections, (chiefly to the want of solidity in the machinery,) from Mr. Miller's want of confidence in its ultimate success, and his attention being diverted to other pursuits, the boat was soon afterwards dismantled, and the engine removed from it. It has been lately stated that about the year 1787 Messrs. Furnau and Ashton made experiments in steam-navigation on the river at Hull, which ended in their building a boat which for some time plied between Beverley and Hull, and another of a larger size, which was bought by the Prince of Wales, afterwards George IV., and fitted up as a pleasure yacht. The latter vessel is said to have been burned: what became of the former is not stated.

From January, 1801, till April, 1803, Mr. Symington was employed by Lord Dundas to make a series of experiments on steam-boats, with the view of their being used on the Forth and Clyde Canal; and the towing-vessel, the "Charlotte Dundas," which he then constructed, appears to have been entirely successful, in so far as regarded moderate power and speed. The use of this vessel, however, on the canal was discontinued in consequence of the injury which it was apprehended the washing of the waves in its wake might do to the banks; and although the Duke of Bridgewater was so satisfied of the advantages of the invention as to have given Mr. Symington an order to build eight similar boats, to be used on his canal, yet the hopes of the enterprising inventor were destined to be crushed just at the very "moment of projection;" for "the same day that he was informed by Lord Dundas of the final determination of the Committee not to allow steam-boats to be employed on the canal, he received intelligence of the death of the Duke of Bridgewater."*

In 1801, Symington's steam-boat was visited, minutely inspected, and tried, by Robert Fulton, a native of Pennsylvania, (the son of an emigrant from Dumfries-shire;) who, as an engineer,—not merely an amateur,—devoted much time and attention to the subject of steam-navigation. And early in 1802, he being then resident in Paris, and in full communication with Mr. Livingstone, the envoy from the United States to France, who appears to have been attached to similar pursuits, he addressed a letter to Mr. James Watt, jun., in which he inquired the price and other particulars of a small engine of five horse-power. In a letter written a week later, he made inquiries as to the employment of high degrees of heat in small engines, and the limit to which it might be carried, in order to render them light and compact,—for this, with his views, was necessarily a cardinal point,—and then he went on to say, "The object of my investigation is to find whether it is possible to apply the engine to working boats up our long rivers in America. The persons who have made such attempts have commenced by what they called improving Watt's engine, but without having an idea of the physics which lay hid in it from common observers; but such improvements have appeared to me like the improvements of the preceptor of Alcibiades, who corrected Homer for the use of his scholars. Their ill success, and their never having found a good mode of taking a purchase on the water, are the reasons why they have all failed. Having, during the course of my experiments on submersive navigation, found an excellent mode of taking a purchase on the water, I wish to apply the engine to the movement. The only thing which is wanting is to arrange the engine as light and compact as possible," &c. And, in the postscript of his letter, he proposes for Mr. Watt's consideration some schemes of engines suggested by Mr. Livingstone: schemes on which we do not find that any opinion was then expressed, but which appear not to have been very clearly explained, and which, in so far as their construction was intelligible, did not promise to be very effective.

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* Woodcroft 'On Steam Navigation,' 1848, p. 55.

On the 6th of August, 1803, Mr. Fulton ordered his first engine from Soho, repeating the application in person in 1804. The diameter of the cylinder was 24 inches, with a stroke of four feet, being about nineteen horse-power. "The principal parts of the engine were made and forwarded early in 1805; the planning and execution of the subordinate parts, as well as of the connecting and paddle machinery, having been undertaken by Mr. Fulton himself. He built a vessel from his designs at New York, called the 'Clermont,'* and having erected the machinery on board of her, the first trial was made in the spring of 1807, and was eminently successful; and this vessel was soon after established as a regular steam-packet between New York and Albany."†

Within six years from the first trial-trip of the "Clermont," six steam-vessels had been built for Mr. Fulton, and were in constant and successful use in America for the conveyance of passengers.

"It is a Mr. Fulton," writes Mr. Watt to Dr. Townsend of Bath,‡ "who has constructed the steam-boats in America: two of the engines have been made by Boulton, Watt, and Company, but the machinery has been made entirely in America, under his own direction. The following is his account of his boat, (Sept.

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* From a residence of Mr. Livingstone's on the Hudson river, about two-thirds of the way from New York to Albany.

† The distance between New York and Albany has, we believe, been ascertained by a recent survey to be 125 geographical miles.

‡ April 13th, 1812.

15th, 1810:)—'The first engine thus in use was 24-inch cylinder, 4-feet stroke, which drove a boat 166 feet long and 18 feet wide, drawing 2½ feet of water, at the rate of 5 miles an hour on the Hudson river; that is, taking the tide for and against the boat, the average velocity is 5 miles an hour.' The boats go regularly between New York and Albany, distant 160 miles, and he is forming similar establishments on other rivers, and has had a second engine of 28-inch cylinder, 4-feet stroke; and one of the latter size has been made to navigate a boat between Montreal and Quebec.

"I am informed by a friend who has seen the steam-boat, that the engine and boilers occupy about one-third of the length of the boat, and that the engine operates by communicating motion to a water-wheel on each side of the boat, which he said were about 6 feet diameter, and 3 feet wide in the sole; but I think they must be of a larger diameter.

"You will readily see that a machine of this kind could not pass bridges and locks, which all our navigations are full of; but might navigate in the tide-way of the Thames or Severn, or other rivers clear of bridges, &c., and sufficiently wide.

"Peter Miller, Esq., of Dalswinton, in Scotland, tried many experiments, ten or more years ago, with a boat of this construction, and might have succeeded if he had had a better engineer. He is now a *very* old man. On the whole, as far as it is at present known to me, I think it would not answer the purpose you want. I believe Mr. Rennie is engineer to your canal: nobody is more able to advise you on this head."

In 1811, Mr. Henry Bell, a citizen of Glasgow, who, since 1800, had repeatedly urged the subject of steam-propulsion on the attention of the British government, and had also aided Fulton with drawings of machinery, &c., took the decided and enterprising step of himself trying in Scotland, at his own risk and under his sole direction, an experiment similar to that which had succeeded so well in America. He had a boat, called from the great heavenly body of that kind which made its appearance in that year, the "Comet," built at Port Glasgow, in the yard of Messrs. J. & C. Wood, which, propelled by a steam-engine of his own construction, was finished by the end of 1811. It plied on the Clyde, between Glasgow and Greenock, early in 1812; and thus became the forerunner of that system of practical steam-navigation which has since so widely extended itself in this country. The "Comet" was forty feet in length, of twenty-five tons measurement, and four-horse power; but other vessels soon followed of somewhat greater dimensions, fitted with engines of proportionally greater powers;—the largest, built in 1813, of which we are aware, being the "Glasgow," of 74 tons and 16 horse-power,—in 1814 the "Morning Star," of 100 tons and 26 horse-power,—and in 1815, the "Caledonia," of 102 tons and 32 horse-power. In that year, two steam-vessels went from the Clyde to the Thames; one by the Forth and Clyde Canal to Leith, and thence by the east coast; and the other by the west coast and round the Land's End:—these being, so far as we know, the first attempts at steam-navigation made in the open sea of our coasts.

"During his last visit to Greenock in 1816," says Mr. Williamson, "Mr. Watt, in company with his friend Mr. Walkinshaw,—whom the author some years afterwards heard relate the circumstance,—made a voyage in a steam-boat as far as Rothsay and back to Greenock,—an excursion which, in those days, occupied the greater portion of a whole day. Mr. Watt entered into conversation with the engineer of the boat, pointing out to him the method of 'backing' the engine. With a foot-rule he demonstrated to him what was meant. Not succeeding, however, he at last, under the impulse of the ruling passion, threw off his overcoat, and, putting his hand to the engine himself, showed the practical application of his lecture. Previously to this, the 'back-stroke' of the steam-boat engine was either unknown or not generally known. The practice was to stop the engine entirely a considerable time before the vessel reached the point of mooring, in order to allow for the gradual and natural diminution of her speed."*

In April, 1817, Mr. James Watt, jun., having purchased the "Caledonia," which from defects in her engines had been little used since her launch in 1815, had her machinery taken out, and replaced by two new engines of Soho manufacture, of 14 horse-power each. In October of that year he went over in her to Holland, and ascended the Rhine as far as Coblentz; having thus been the first to leave the British shores and cross the Channel by so novel, and, as it was then esteemed, so hazardous a mode of transit.

The "Caledonia" having left Margate on the 14th of October, 1817, arrived off West Kapelle, Walcheren, in ten minutes more than twenty-four hours, and come to anchor in the Keeting near Vianen three hours later; having run, under steam, at an average speed of 7½ knots an hour. In her voyage from Rotterdam to Cologne, by Nimeguen, Emmerick, Wesel, and Düsseldorf, the time actually occupied under way, with a strong easterly wind and current against the vessel during the whole of it, and for nine hours only one engine at work, was 48 hours, 52 minutes.

On her homeward voyage from Coblentz, the "Caledonia" entered the Scheldt, and visited Antwerp. She was then laid up for part of the winter in the harbour of Rotterdam, for repairs and alterations. After her return to the Thames in the spring of 1818, Mr. J. Watt, jun., made no fewer than thirty-one series of experiments with her on the river, (the whole number of those experiments amounting to two hundred and fifty); † which resulted in the adoption of many most material improvements in the construction and adaptation of marine engines, and in an immense, though gradual extension of that branch of the manufacture at Soho. From the particulars already given of the amount of steam-power produced at that establishment, it appears that the marine engines manufactured there, up to 1854, were in number 319; of 17,438 *nominal*, or 52,314 *real* horse-power.*

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* 'Memorials of Watt,' p. 234.

† From a memorandum made by one of the party present on the occasion, we find that on the 14th of July in that summer, the "Caledonia" steamed to the Nore and back—nearly 100 miles—in ten hours; to the great astonishment, among others, of a French gentleman on board, and the delight of Chantrey, the sculptor, who was another member of that party of pleasure.

The memory of James Watt will now be worthily perpetuated in the British navy, by the fine screw steam man-of-war of that name, of 91 guns; which was launched at Pembroke dock-yard in 1853, and fitted with Soho engines.†

With regard to another application of steam-power, of kindred interest and importance, that, viz., to locomotion on land, it is remarkable enough that when Mr. Watt's attention was first directed, by his friend Robison, to the steam-engine, "he (R.) at that time threw out an idea of applying the power to the moving of wheel-carriages." "But the scheme," adds Mr. Watt, "was not matured, and was soon abandoned on his going abroad." ‡

It may be here incidentally mentioned that the Abbé Huc, in giving an account of the character and career of Father Verbiest, a successful Jesuit missionary among the Chinese, who died in 1688, says:—"It is highly probable, that he anticipated the great discovery of modern times, the motive power of steam. In his learned work, entitled 'Astronomia Europæa,' there is a curious account of some experiments that he made at Pekin, with what we may call steam-engines. He placed an æolipile upon a car, and directed the steam generated within it upon a wheel to which four wings were attached; the motion thus produced was communicated by gearing to the wheel of the car. The machine continued to move with great velocity as long as the steam lasted; and by means of a kind of helm, it could be turned in various directions. An experiment was made with the same instrument applied to a small ship, and with no less success; and Father Verbiest, after giving an account of these experiments, adds these very remarkable words:—'*Dato hoc principio motûs, multa alia excogitari facile est.*'"[*]

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* See p. 321, *suprà.*

† The engines in question, as we have been informed by one of their makers, were originally intended for the "Vulcan," to exert the power of 700 horses at 60 strokes per minute; in the "James Watt," owing to the employment of a larger size of screw-propeller, they are only to make 50 strokes per minute, and the estimate of their power will be reduced to that of 600 horses. In casting the fine brass screw-propeller for H.M.S. the "James Watt," *ten tons and a half* of metal were employed.

‡ Robison, p. 113.

In August, 1768, Dr. Small informed Mr. Watt that "Mr. Edgeworth, a gentleman of fortune, young and mechanical, and indefatigable," had "taken a resolution of moving land and water carriages by steam," and had made considerable progress for the time he had employed himself in that line. "He knows nothing," added Dr. Small, "of your peculiar improvements, but seems to be in a fair way of knowing whatever can be known on such subjects."[†] In allusion to the same subject, Dr. Small wrote to Mr. Watt a month later, "Your very clever friend Mr. Robison and his pupil passed Friday evening with me to my great satisfaction. I told them I hoped soon to travel in a fiery chariot of your invention."[‡] Seven months later, "A linen-draper at London, one Moore, has taken out a patent for moving wheel-carriages by steam. This comes of thy delays. I dare say he has heard of your inventions. Do come to England with all possible speed. At this moment how I could scold you for negligence! However, if you will come hither soon, I will be very civil, and buy a steam-chaise of you, and not of Moore. And yet it vexes me abominably to see a man of your superior genius neglect to avail himself properly of his great talents."[§] Mr. Watt, in writing to Dr. Roebuck of this, says, "This was a thing I hoped to accomplish by the circular engine,"[‖] [or steam-wheel.] And he replies to Small:—"If linen-draper Moore does not use my engine to drive his chaises, he can't drive them by steam. If he does, I will stop them. I suppose, by the rapidity of his progress and puffing, he is too volatile to be dangerous."—"You want a steam-chaise; pray make one. I give you leave, and will also give you advice,—not gratis, however, but for good deeds done and to be done."—"Of all things in life, there is nothing more foolish than inventing. Here I work five or more years contriving an engine, and Mr. Moore hears of it, is more *éveillé*, gets three patents at once, publishes himself in the newspapers, hires 2000 men, sets them to work for the whole world in St. George's Fields, gets a fortune at once, and prosecutes me for using my own invention!"*

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[*] Huc's 'Christianity in China, Tartary, and Thibet,' vol. iii. 1858.

[†] Dr. Small to Mr. Watt, 12th August, 1768.

[‡] The same to the same, September, 1768.

[§] Dr. Small to Mr. Watt, 18th April, 1769.

[‖] Mr. Watt to Dr. Roebuck, 28th April, 1769.

In the seventh "new improvement," however, set forth in the specification of his patent of 1784, Mr. Watt described the principles and construction of "steam-engines which are applied to give motion to wheel-carriages for removing persons or goods, or other matters, from place to place, in which cases," he says, "the engines themselves must be portable. Therefore, for the sake of lightness, I make the outside of the boiler of wood, or of thin metal, strongly secured by hoops, or otherwise, to prevent it from bursting by the strength of the steam; and the fire is contained in a vessel of metal within the boiler, and surrounded entirely by the water to be heated, except at the apertures destined to admit air to the fire, to put in the fuel, and to let out the smoke; which latter two apertures may either be situated opposite to one another in the sides of the boiler, or otherwise, as is found convenient; and the aperture to admit air to the fire may be under the boiler. The form of the boiler is not very essential, but a cylindric or globular form is best calculated to give strength. I use cylindrical steam-vessels with pistons, as usual in other steam-engines, and I employ the elastic force of steam to give motion to these pistons, and after it has performed its office I discharge it into the atmosphere by a proper regulating valve, or I discharge it into a condensing vessel made air-tight and formed of thin plates or pipes of metal, having their outsides exposed to the wind, or to an artificial current of air produced by a pair of bellows, or by some similar machine wrought by the engine or by the motion of the carriage; which vessel, by cooling and condensing part of the steam, does partly exhaust the steam-vessel, and thereby adds to the power of the engine, and also serves to save part of the water of which the steam was composed, and which would otherwise be lost. In some cases I apply to this use engines with two cylinders which act alternately; and in other cases I apply those engines of my invention which act forcibly both in the ascent and descent of their pistons, and by means of the rotative motion in figure 20th,* or of any other proper rotative motion, I communicate the power of these engines to the axis or axle-tree of one or more of the wheels of the carriage, or to another axis connected with the axle-tree of the carriage by means of toothed wheels; and in order to give more power to the engine when bad roads or steep ascents require it, I fix upon the axle-tree of the carriage two or more toothed wheels of different diameters, which when at liberty can turn round freely on the said axle-tree when it is at rest, or remain without turning when it is in motion; but, by means of catches, one of these wheels at a time can be so fixed to the axle-tree, that the axle-tree must obey the motion of the toothed wheel, which is so locked to it. And upon the primary axis, which is immediately moved by the engine, or which communicates the motion of the engine to the axle-tree of the carriage, I fix two or more toothed wheels of greater or lesser diameters than those on the axle-tree, which are moved by them respectively, so that the wheels on these two axles having their teeth always engaged in one another, the wheels on the axle of the carriage always move with the wheels on the axle of the rotative motion, but have no action to turn the wheels of the carriage except one of them be locked fast to its axle-tree,—then the latter receives a motion faster or slower than that of the axle of the rotative machinery, according to the respective diameter of the wheels which act upon one another. In other cases, instead of the circulating rotative machinery, I employ toothed racks or sectors of circles worked with reciprocating motions by the engines, and acting upon ratchet wheels fixed on the axles of the carriage. And I steer the carriage, or direct its motion, by altering the angle of inclination of its fore and hind wheels to one another by means of a lever or other machine. As carriages are of many sizes and variously loaded, the engines must be made powerful in proportion. But to drive a carriage containing two persons, will require an engine with a cylinder seven inches in diameter, making sixty strokes per minute of one foot long each, and so constructed as to act both in the ascent and descent

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* Mr. Watt to Dr. Small, 28th April, 1769.

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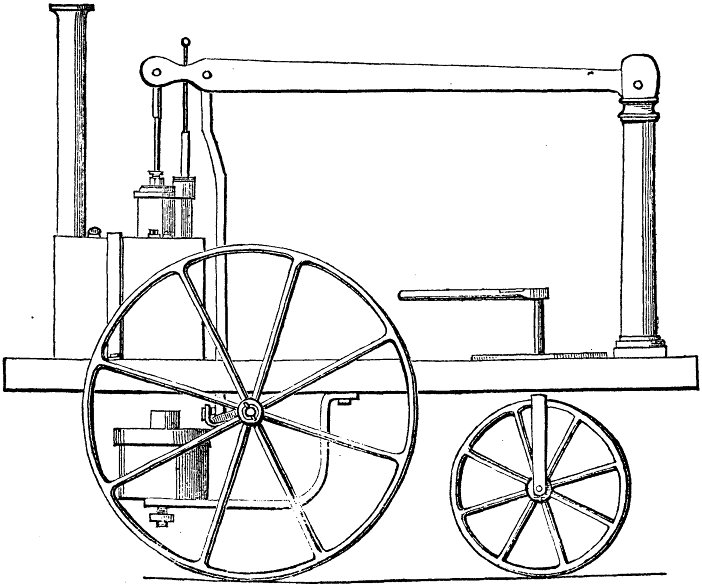
* A sun-and-planet wheel.



Working Model of a Locomotive Engine made by Mr. W. Murdock in 1784.

of the piston; and the elastic force of the steam in the boiler must occasionally be equal to the supporting a pillar of mercury thirty inches high."

Also in 1784, Mr. Murdock made a working model of a locomotive engine upon the principles so specified by Mr. Watt, which performed well, and is still in existence. With a spirit lamp for a furnace, its cylinder attached to the boiler, and its piston-rod working a beam that turned the driving wheels by a crank, it was placed in the Great Exhibition of 1851,[*] where it attracted much notice. It stood among the "machinery at rest," on the colossal marine engines of 700 horse-power, manufactured by Messrs. James Watt and Co., which have since been erected in the fine 91 gun screw steam-ship the "James Watt;" and by the side of that interesting little model was placed another, also of diminutive size, of a steam-engine with *an oscillating cylinder*, invented and constructed by Mr. Murdock in the year 1785. The model of the locomotive engine is now in the possession of Messrs. James Watt and Co.; that of the oscillating cylinder remains, a valued heirloom, in the family of Mr. Murdock.[†]

In reference to this specification, Mr. Watt writes to Mr. Boulton,[‡] "I have given such description of engines for wheel-carriages as I could do in the time and space I could allow myself; but it is very defective, and can only serve to keep other people from similar patents." And ten days later,[§] "I wrote to you last night, and now sit down to give you some of my ideas on the wheel-carriage scheme, and have therefore annexed that article of the specification, by which you will see the general idea. The engine may either be connected with the rotative motion by a working-beam, or may be placed directly over the secondary axle, and work the rotative motion by means of two rods coming down on each side of the cylinder from a cross-bar on the top of the piston-rod, guided perpendicularly by a sliding frame; but I am inclined to prefer a working-beam, which in this case may be short. I do not know that the organ-pipe condenser will make much vacuum, but it may, by the *help of the bellows*, condense, and save most of the water. On the side you have a sketch of the two axles, and of the means I use to lock and unlock the wheels which connect them together, so as to make the carriage go faster or slower at pleasure, or, at least, to have more or less power at will. The piece (*a b*) slides in a hollow, and two slits in axle of the carriage; when *b* is in the place drawn, the rotative motion can turn without moving the carriage; but when *b* is placed so as to be in a slit which is in one of the wheels, then the wheel will cause the axle to turn round or to break *b* and *b* is always disengaged from one wheel before it is locked to the other. As to the size of the cylinder, boiler, &c., I calculate that, suppose the power necessary to move a post-chaise on a plain to be 80 lbs. weight, and the chaise to move at the rate of 4 miles per hour, or 6 feet per second, let the moving-wheel be 4 feet diameter, then it will make 1 revolution in 2 seconds, and if the engine makes 60 strokes per minute, it will make one revolution for 2 strokes; but as the rotative motion will make 2 revolutions per stroke, it will make 4 revolutions for each turn of the wheel of the carriage, and 80 lbs. × 6 feet = 480 lbs. 1 foot high per second, and supposing the stroke of the engine 1 foot long, 480 ÷ 2 must be its power = 240 = 6 lbs. on inch to a 7-inch cylinder; but as going up hills it will require a power of 400 lbs. to drag the chaise up, the

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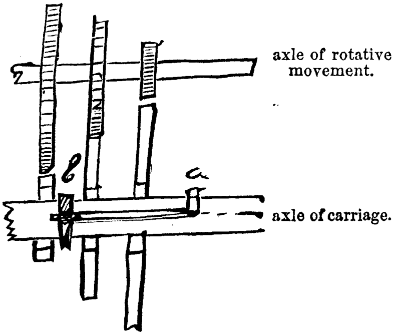
[*] See the 'Official Catalogue,' vol. i. p. 211.

[†] Both of these curiosities of the engineering art were, by the permission of their respective proprietors, delineated and engraved for the 'Mechanical Inventions of Watt;' see vol. iii. plates XXIX. and XXXIV.

[‡] 17th August, 1784.

[§] 27th August, 1784.



power in these cases must be increased 5 times, that is, *the axle* of the carriage must make only 1 turn for 20 turns of the rotative axle, and will then move only 12 feet in 10 seconds; but this inconvenience may be something lessened by letting the steam get stronger at such times.

"A cylinder of 7 inches diameter and 12-inch stroke will take something more than ½ a foot of steam per double-stroke, supposing it to be working with a condenser; consequently it would take 30 cubic feet of steam per minute = 1800 feet of steam per hour, which, supposing it to be equal to 1 cubic foot of water, would require a boiler of 8 feet surface exposed to the fire to make any tolerable performance in respect of fuel; but as we can *depend* on no aid from condensation, we must suppose this steam to be at least 1½ times as dense as the common steam, therefore there must be a surface of 12 feet exposed to the fire, if not more; let us leave the form of the boiler out of the case at present. The surface of 12 square feet which we suppose to be exposed to the fire, must be covered with a shell of water of some thickness, which, upon the average, I shall suppose to be 6 inches thick, which will make the whole quantity of water necessary = 6 cubic feet, supposing no magazine of water to be carried. As we must suppose the copper of the boiler which is to stand such violent steam to be at least ¼ inch thick, it will weigh at least ten lbs. per square foot; we have then 120 lbs. for the inside part of the boiler; and as there must be steam-room, and the outside case of the boiler must be 1 foot wider than the inside, supposing the inside oblong 1 foot wide, 3 feet long, and 18 inches high, then the outside must be 4 feet long, 2 feet wide, and 2½ feet deep, which would have 35 feet surface, which at 10 lbs. would weigh 350 lbs. The boiler, then, with the included water, would weigh 830 lbs., without any allowance for a grate or wooden case; but, in relation to the latter, the copper might be made so much thinner as to allow for it, and perhaps some means may be hit upon to make the boiler cylindrical, with a number of tubes passing through, like the organ-pipe condenser, whereby it might be thinner and lighter; but I fear this would be too subject to accidents. Let us suppose, however, that it could be reduced to 300 lbs. weight, which, with the water, would make 660 lbs.

	lbs.
"A post-chaise weighs about	1000
"The boiler and water would weigh	660
"The engine and wheels, say about	200
"The fly, 3 feet diameter, containing the power of one stroke of the engine	100
"The organ-pipe condenser and bellows, say	100
"Three persons, including the driver	400
"Their luggage	200
"Coals for four hours, at 15 lbs. per hour	60
"And if the organ-pipe condenser is not found sufficient to condense the steam, water must be carried, say for two hours	180
	2900

"And then, if the machinery cannot be made lighter than has been stated, the power will, I am afraid, prove insufficient, and a further augmentation of the boiler, &c., must take place. If there were no friction, the power of 80 lbs. would be sufficient to draw the carriage up an ascent of 1 in 36 on a hard smooth plain; but there would be some friction, and roads are both unequal and generally soft, which latter gives a continued resistance of the same nature as going up a steep ascent. There is another consideration, which is, that the carriage, being loaded with the weight of the engine, would require stronger wheels than usual for these machines, which would still increase its weight.

"I have taken it for granted all along that 80 lbs. is a sufficient force to move a common post-chaise, loaded as I have mentioned, (but without the engine); which, however, I am by no means certain of. I rather apprehend it will require that power on a quite plain road, and more upon acclivities; for four men would be able to exert that force, and yet could not move the loaded post-chaise at the above rate; and I observe that horses labour as much in a cart as they do in a horse-mill, yet they exert near 200 lbs. each in the latter, at the rate of 1½ miles per hour.

"31 August, 1784.

"The whole matter seems to turn on an answer to the question, whether 80 lbs. be a sufficient power to move a post-chaise on a tolerably good and level road at the rate of 4 miles in an hour. 2dly. Whether any less surface than 8 feet exposed to the fire be sufficient to evaporate a cubic foot of water per hour, without much waste of fuel; which question seems partly answered by the boiler of our corn-mill, which has only about 5 feet surface exposed to the fire for each foot it evaporates per hour; and it evaporates about 8 cubic feet per cwt., so that by submitting to a waste of coals, a smaller boiler would do. 3rdly. Whether it will require steam of more than 1½ times atmospheric density to cause the engine to exert a power = to 6 lbs. on the inch, which I fear it will. I think that the cylinder must either be made larger, or make more than 60 strokes per minute; and I do not think the latter plan very advisable, principally because the rotative motion already turns too fast for the axle of the chaise, and that it will require more wheels than two to reduce the motion to the proper velocity. As to working-gear, stopping and backing, with steering the carriage, I think these articles perfectly manageable.

"The proper place for the engine will be behind the carriage, and to act upon the hind-wheels. Cokes must be used in place of coals, to prevent the disagreeable circumstances of soot and smoke; but there will be no avoiding the sulphureous air, which, when going before a gentle wind, will prove suffocating. The shaking of the carriage will supersede the necessity of poking the fire, but will be apt to waste the coals, by making the cokes fall through the grate before they are consumed. The shaking of the carriage will be apt to derange the joints of the cylinder, &c., and render them untight; but perhaps some remedy may be devised for this in construction.

"My original ideas on this subject were prior to my invention of these improved engines, or before the crank or any other of the rotative motions were thought of. My plan then was to have two inverted cylinders, with toothed-racks instead of piston-rods, which were to be applied to two ratchet-wheels on the axletree, and to act alternately; and I am partly of opinion that this method may be applied to advantage yet, because it needs no fly, and has some other conveniences.

"From what I have said, and from much more which a little reflection will suggest to you, you will see that without several circumstances turn out more favourable than has been stated, the machine will be clumsy and defective, and that it will cost much time to bring it to any tolerable degree of perfection; and that for me to interrupt the career of our business to bestow my attention on it would be imprudent. I even grudge the time I have taken to write these comments on it. There is, however, another way in which much mechanism might be saved, if it be in itself practicable, which is, to apply to it one of the self-moving rotatives, which has no regulators, but turns like a mill-wheel by the constant influx and efflux of steam; but this would not abridge the size of the boiler, and I am not sure that such engines are practicable." The remainder of this letter is occupied with the consideration of the arrangements proper to be made with a third party, (not named, but then in the employment of Messrs. Boulton and Watt, and known to have been Mr. William Murdock), in case of his prosecuting the design, which he appears at that time to have warmly entertained, and urged, of making steam wheel-carriages for sale to the public, under a licence from his employers, or in partnership with them.

Again,* "I am extremely sorry that W[illiam] M[urdock] still busies himself with the steam-carriage. In one of my specifications I have secured it as well as words could do it according to my ideas of it; and if to that you add Symington's and Sadler's patents, it can scarcely be patentable, even if free of the general specification in the Act of Parliament; for even granting that what I have done cannot secure it, yet it can act as prior invention against anybody else, and if it cannot be secured by patent, to what purpose should anybody labor at it? I have still the same opinions concerning it that I had; but to prevent as much as possible more fruitless argument about it, I have one of some size under hand, and am resolved to try if God will work a miracle in favour of these carriages. I shall in some future letter send you the words of my specification on that subject. In the meantime I wish W[illiam] could be brought to do as we do, to mind the business in hand, and let such as Symington and Sadler throw away their time and money, hunting shadows." And, a few days later,* "You are certainly wrong in your computation of 18 lbs. of water serving your steam-carriage an hour. At present, where engines are wrought by condensation, to exert the force of one horse requires 10 lbs. of coals and 1 cubic foot of water per hour; but if steam of double density is used, as must be the case where there is no condensation, it will take 20 lbs. of coals and 2 cubic feet of water for each horse-power. These are the present facts, and I suspect the age of miracles is past. I am glad, however, that William applies to his business." And, to Dr. Black,† "You know I have long had plans of moving wheel-carriages by steam, and I have even described them in one of my patents some years ago. I believe I shall make some experiments on them soon, but have small hopes of their ever becoming useful."

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* 12th September, 1786.

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* 23d September, 1786.

† 5th October, 1786.

CHAPTER XXVI.

NEW LAMPS—GRAVIMETER—CAOUTCHOUC TUBES—ARITHMETICAL MACHINE—ARTICULATED WATER-PIPE—MACHINE FOR COPYING SCULPTURE—ITS GRADUAL PROGRESS AND ITS PERFORMANCES—DATES AND EXTRACTS FROM MSS. CONCERNING IT—INTENDED SPECIFICATION OF A PATENT FOR ITS INVENTION—RELATIVE DRAWINGS—TIME EMPLOYED IN ITS OPERATIONS—PERFECTION OF THE WORK DONE.

BY another of what may be called his mechanical recreations, practised soon after the date of the last of his steam-engine patents, Mr. Watt seems to have realised the idea, made classical by the story of Aladdin, of "New lamps for old." For the following letter to Mr. Argand,* famed for his manufactures of that sort, contains various ingenious suggestions on the subject of better reading-lamps than had before existed; and for a long time lamps were made at Soho on Mr. Watt's principles, which gave a light surpassing both in steadiness and brilliance anything of the kind that had appeared in those comparatively dark ages; and which, indeed, we have seldom, if ever, seen equalled by the elaborate contrivances so much vaunted in our own days of more general illumination.

"I have just seen some of Keir's lamps, but have not seen them tried; in my opinion, they will be found troublesome, and subject to be out of order; for the quality of the saline liquor must be adjusted to a drachm, otherwise they will not answer; besides, I should suspect that said liquor will have bad effects upon the oil, or upon the vessels containing it. I am sure they are clumsy, logger-headed things, top-heavy, and liable to be overset.

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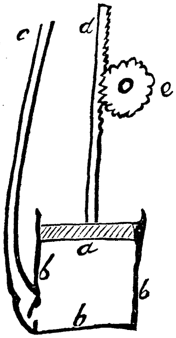
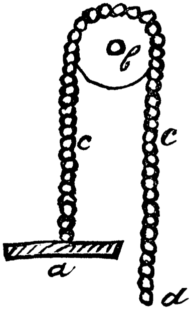
* August 8th, 1787.

"I have four plans for making lamps with the reservoir below, and the stem as tall as you please. The first is, by means of a watch fixed above the reservoir, which shall work a small forcing-pump, about the size of a quill, at proper intervals, and keep the burner always supplied; and it may be so contrived as to stop the water while the oil is within certain limits in height of the feeder of the burner.



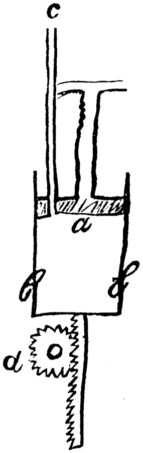
a Piston.
bb Pump.
c Feeding-tube.
d Stem and rack.
e Wheel on spring barrel.

View of Chains and Pulley.



a Piston.
b Pulley.
c Chain.

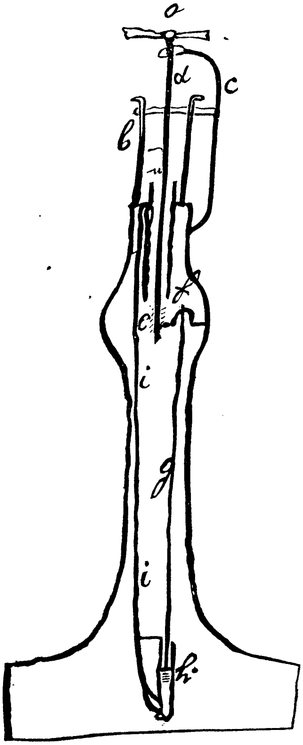
"Second, by means of a pump about 3 inches diameter and 3 inches stroke, with a *light* piston fixed to it, garnished with a pliable leather, made to go easy, and perfectly oil-tight. The stem of this piston, which guides it perpendicularly, to be pressed down by a clock or timepiece spring in a barrel, acting on the stem by a wheel and rack-teeth on the stem; but as the spring will grow weaker as it unbends, and the pillar of oil will grow heavier as the piston descends, to regulate these inequalities I attach to the piston one end of two heavyish chains, which lie over two pulleys, at some considerable height above; so that, as the piston descends, more weight of the chains will come to that side, and assist it in the descent.



a The piston fixed.
bb The pump moveable.
c The feed-pipe.
d Wheel on spring-barrel

The end (*d*) of the chain must be always heavier than the other, so that it may keep it tight.

"Third, instead of making the piston moveable as in the last, make it fixed; carry the feeding-pipe out of its upper surface; let the pump be moveable upwards by means of a spring and barrel; then, as the spring grows weaker by unwinding itself, the height of the column of oil and the weight in the pump will both grow less, in a ratio to which it is possible to adjust a spring.



a Fly. *b* Glass. *c* Glass-holder.
d Spindle. *e* Endless screw. *f* Crank.
g Pump-rod. *h* Pump. *ii* Feed-pipe.

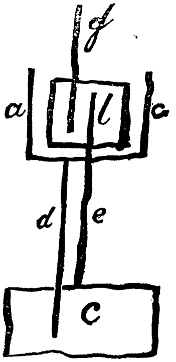
"In order to avoid too much height, the pump may be pulled up by two racks, fixed to the upper edge, and acted upon by two wheels on the axis of the spring barrel.

"Fourth, last, and best. Let there be placed, about 2 inches above the upper end of the glass cylinder, a small fly like that of a smoke-jack, which will turn round very swiftly by the current of air, and pretty forcibly. Let this fly have a stem coming down in the inside of the inner cylinder: at its lower end let there be an endless screw of one thread, working into a wheel of 60 or 100 teeth, which will make one turn for every 60 or 100 revolutions of the fly; on the axis of this wheel let there be a crank, (*manivelle*), to which attach the piston of a small pump about the size of a goosequill, and ½ an inch or ⅜ inch stroke, which will always keep the lamp abundantly supplied with oil, and a waste-pipe may convey back the superfluity.

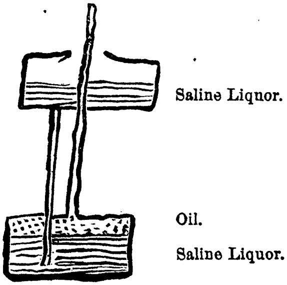
I once thought of making it work a rope-pump, but the crank will be better, and amadou will make an excellent piston; *expertus sum* the amadou.

"Now, if this will answer, it will be the To Καλον, the To To Μεγιστον, because it will perform its office by its own *vis insita.* The fly, indeed, will darken a small space above it, but it will serve to amuse people, and consequently will sell if well made. In short, I like it so well, that if you will try it, and find it answers, I will go half with you in a patent for England, if you choose it; otherwise, it is entirely at your service to make what use of it you please.

"Keir's lamp has, however, one good property which this will not have, viz., as his pillar of saline liquor grows shorter, the pillar of oil grows shorter too. Keir's lamp may be improved in this way:—let *aa* be an open vessel containing oil, and *bb* be a close vessel containing the same fluid, *c* a vessel containing air; then the oil in *aa* will descend into the vessel *c*, by *d*, and the air will ascend by the pipe *e* into the upper part of *b*, and will force the oil in it to ascend by the pipe *f* as much above *b* as the surface of oil in *c* is below the surface in *aa*. By this means you will be quit of the saline liquor and all its embarrassments, and you may carry the burner higher than he can; and if you use a

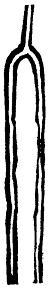


Keir's Lamp.



saline liquor in *aa*, you may carry it twice as high as he does. Q. E. D. *Sat verbum sapienti. Valeant quantum valere possunt*, &c., &c., &c."[*]

About a year after the date of the above letter, Mr. Watt made a pretty instrument for determining the specific gravities of liquids, having, he says, improved on a hint he had taken. "It consists of a syphon of two equal legs, with a tube joined to the bend of it, and a little water in that tube. One leg being immersed in water, and the other in the liquid to be examined, by sucking at the pipe the liquors will both rise to columns proportioned to their specific gravities; and, if it is about 13 inches long in the legs, you can easily judge within $\frac{1}{400}$ part of the specific gravity, or, rather, of the longest column suspended."[†]



So late as 1856 we have read the following announcement from St. Petersburg, showing that Mr. Watt's method is not without its followers even in the present era of more exact science:—"A very simple contrivance has been arranged by A. Meyer, for measuring the specific gravity of solid and fluid bodies. It consists of a glass cylinder, (I presume, a precipitating glass,) a glass tube in the form of a syphon, and a brass screw vice for holding the syphon."[‡]

Little more than a year after the date of the specific-gravity machine, he says that he had "found out a method of making tubes of the elastic resin, without dissolving it," which recipe he offered to give to his friend the Chevalier Landriani. We have not found this method described in any subsequent letter of Mr. Watt, of which a copy has been preserved; but the subject of it was one which excited considerable interest at that time, and the importance of such tubes for a thousand purposes in science and the arts, is now universally understood. Winch and Cavallo's mode of dissolving caoutchouc in sulphuric æther, and forming tubes by dipping cylindrical clay moulds into the viscous solution, as described in works of that date, received great attention from chemists both in this country and on the Continent, as supplying a great desideratum in the apparatus of the laboratory." *

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[*] To Mr. Argand, 8th August, 1787.

[†] To Dr. Black, June 8th, 1788.

[‡] 'The Times,' 8th March, 1856.

The arithmetical machine, on which Mr. Watt says, in 1785, that he had been turning "some of his idle thoughts," † he does not appear ever to have prosecuted further than by mentally considering the manner in which he could make it perform the processes of multiplication and division: processes which may be held to imply the earlier steps of addition and subtraction.

Another of his contrivances, happy in its conception, and less difficult of completion than the arithmetical machine would of necessity have been, belongs to the early part of the present century. He was about that time consulted by the company of proprietors of the Glasgow Waterworks, as to a difficulty that had occurred in laying pipes to bring pure spring water across the river Clyde, to the company's engines at Dalmarnock: the channel of the river being there covered with mud and shifting sand, full of inequalities, and subject to the pressure of a considerable body of water. A long and flexible, or rather, articulated suction-pipe, with joints formed on the principle of those in a lobster's tail, and so made capable of accommodating itself to

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* See the 'Travels of St. Fond,' vol. i. pp. 28–34.

† "I have been turning some of my idle thoughts lately upon an arithmetical machine: how I shall succeed I know not, not having made it yet. Its properties are to be, that when you want to multiply, you first turn up one figure of the multiplier, you then turn up in their order all the figures of the multiplicand, and the machine will show the product by that multiplier; you then turn up the second figure of the multiplier, and, beginning one place towards the left hand, you turn up again all the figures of the multiplicand, and the machine shows the product by these two figures ready added, and so on for any number of figures; and it will perform division nearly as easily, without the least calculation or burthen to the memory, other than to take the figures in their order, beginning at either end you like. I intend to make an attempt at making it;—I say an attempt, for though the machine is exceedingly simple, yet I have learnt by experience that in mechanics many things fall out between the cup and the mouth."—*Mr. Watt to Mr. De Luc, 11th December,* 1785.

all the actual and possible bendings at the bottom of the river, was at once recommended by him. This crustacean tube, two feet in diameter, and one thousand feet in length, was executed, from his plans and drawings, by Messrs. Boulton and Watt, and was found to succeed perfectly in practice. Although Mr. Watt's services "were induced solely by a desire to be of use in procuring good water to the city of Glasgow, and to promote the prosperity of a company which had risked so much for the public good," they were handsomely acknowledged by the presentation to him of a piece of plate, of the value of one hundred guineas. An account of the flexible water-pipe, accompanied by an engraving of the drawing sent by Mr. Watt, was communicated by the late Sir John Robison to the 'Edinburgh Philosophical Journal' in 1820.*

As he mentioned to Count Berthollet and others of his correspondents, in 1810, Mr. Watt had for several years felt disabled, by the state of his health, from making chemical experiments. But, as he used to say, "without a hobby-horse, what is life?" and one engrossing occupation, nearly akin to those of his earlier, but what we can hardly call his better days, he also found in gradually perfecting a sculpture-machine: a highly ingenious invention, the idea of which was suggested to him by an implement he had seen and admired in Paris in 1802, where it was used for tracing and multiplying the dies of medals.

Of the exact date when he began to construct the first parts of this novelty in the engine department, we have been unable to find any precise note. In 1791 he wrote to Dr. Black that he had been employed for some time on an artificial alabaster, which he had brought nearly to the hardness and transparency of marble,—very much harder than any natural alabaster; and, although he does not mention how this artificial alabaster was made, many of the specimens of the performance of his sculpture-copying-machine were afterwards made of a similar material.

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* Edinburgh 'Phil. Journal,' vol. iii. p. 60.

The first clear indications that we have met with of his making use of anything that approached to the reality of such a machine, occur in 1807 and 1808, when its construction appears to have been considerably advanced, and he got from London some models to copy,—"small busts of Socrates and Aristotle, and a sleeping boy, sent by Turnerelli, the sculptor."* He then also ordered some diamond cutting-pencils for what he termed his "Parallel Eidograph."† By April, 1809, he had "made considerable progress with the carving-machine, and it seemed necessary to christen it with a Greek name," which to Professor Young, then the accomplished Professor of Greek at Glasgow College, he suggested might be Iconopoia, Iconurga, Iconoglypta, Agalmatopoia, Glyptes, Polyglyptes, Glyptic machine, &c., names to which he afterwards added those of Bust-lathe, Statue-lathe, Pantograph, Double Pantograph, and Double Parallel-lathe. At the same time he got for it, besides gouges and other tools,‡ "drills made in steel frames of peculiar construction, to turn with great velocity and without a shake;" and before the end of May of that year he wrote to his friend, Dr. P. Wilson, that he had now made the glyptic machine polyglyptic, as he could do two or more copies at once, but that it was "still far short of his ideas: *Ars longa, vita brevis*." At the same date he informed his son James that since getting his new drill-frames from Manchester, (where they had been made by a skilful workman of the name of Green, under the immediate superintendence of the eminent machinist Peter Ewart,) he had tried them only so far as to find that he could work two drills at once, and that he had finished "a large head of Locke in yellow wood, and undercut, and a small head of Dr. [Adam] Smith, in ivory, which were both done on the iron platform: the former not so well," he adds, "as I expect to do, but very well." Other occupations interfered to prevent his doing other carvings at that time.

Six weeks later§ he explains to Professor Young the origin of the machine, which was now so far advanced, saying, "There is a machine of the nature of a turning-lathe, which copies medals and other things in bas-relief; it is called in France *tour à médailles*, in English the *likeness-lathe*. I have thought of some improvements on it, which somewhat extend its uses; (this is at present a secret, which I do not wish to be spoken of.") Throughout that and the following year he gave various directions to Mr. Murdock, then, as always, his most able assistant at Soho, and to Mr. Peter Ewart at Manchester, who gladly performed for him the like friendly offices, as to the improvement of some of its separate parts, observing to the latter gentleman, "You know my anxiety to complete it while I can."* To his friends, MM. Levêque and Berthollet also, he described the stage of its progress at which the machine had arrived, and his intention, if he should live to complete it, of communicating a full account of its construction to them.† "I still do a little in mechanics: a part of which, if I live to complete it, I shall have the honour of communicating to my friends in France." And, "I have turned my attention to mechanics whenever my health permitted, and have, as I hope, nearly completed a machine which promises to be of use in the imitative arts, and of which, if I am enabled to complete it, I shall send you a description; but at present I do not like to say much upon a matter *in prospectu*—I wish to speak *de facto*. Whatever may be its success, it has at least had the good effect of making me avoid many hours of ennui, by employing my hands when I could not employ my head, and [has] given me some exercise when I could not go out."‡

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* 25th July, 1807.

† November, 1808.

‡ 30th May, 1809.

§ 7th July, 1809.

Early in 1811 he wrote to Dr. P. Wilson that his invention continued to succeed, and that he had realised some more of his ideas on the subject, having, by very accurate construction of the machine and adjustment of the tools, &c., overcome the difficulty of getting "the several segments which form the surface of the bust to meet;" and having executed several small busts in alabaster, he "not being strong enough to work marble."§ "It requires a very accurate construction of the machine, and a very accurate adjustment of the tools, so that their axes may be always equally distant from each other, as the axes of the pattern and that of the stone to be cut are." Also, that whereas the specimens Dr. Wilson had seen were done by the cutting-tool and the guide-point moving in parallel lines, which were either straight or circular, and very near each other,—("an illustration of Euclid's position, that the motion of a point generates a line, and the motion of a line generates a surface,")—he had now contrived, though not executed, that the two "points, the guiding and the cutting-point, might move in any line, straight or crooked, square or diagonal, so that an inscription might be cut in stone from a drawing on paper." "The principle is the making a drill, or, in some cases, a sharp point, walk over the work to be done, in some given ratio to the motions of a blunt point upon the pattern; but there is some art," he observes, "in making a drill, while continually varying its situation, turn round regularly with any desired velocity; and, on the whole, there is some art required in the use and application of the tools, which experience only has taught me."*

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* 3d May, 1810.

† 14th March, 1810.

‡ 26th December, 1810.

§ 7th March, 1811.

During the next three years, notwithstanding that the "garret," in which the machine and all its appurtenances were placed, was too hot in the heat of summer,† and too cold in the depth of winter,‡ for the old man to spend much time under its roof, the progress he still was making, and the interest he continued to feel in his curiously skilful process, were attested by "very smooth work on an Egyptian head" he was cutting in mahogany,§ as well as by "a little figure of a boy lying down, and holding one arm, very successfully done; and another boy, about six inches high, naked, and holding out both his hands, his legs also being separate."

"The band-guide fully answers expectation, and even follows the motions of the frame faster than I hoped. The axis bends a little, but not injuriously: it would have been better a hollow tube. The turned-up edged tool makes very smooth work on an Egyptian head I am cutting in mahogany. I cannot manage the twisted tools on wood; they will occasionally set in their claws and split off pieces; but the four-toothed tool is more manageable, and works faster."*

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* To Mr. P. Ewart, 9th May, 1811.

† To Mr. P. Ewart, 11th July, 1811.

‡ To the same, 27th February, 1814.

§ To Mr. Murdock, 7th December, 1812.

"But I have been principally employed," he adds, "in making drawings for a complete machine, all in iron, which has been a very serious job, as invention goes on very slowly with me now."

Mr. Murdock soon finished the manufacture of the "new loom, which looks very scientific and answers its purpose," and Mr. Watt, although still seeing "so much to be done," that he feared he should never accomplish it, or that, when done, it would not be worth the trouble, otherwise than as a mental and bodily exercise, had, by March, 1814, "succeeded tolerably in making drills for working marble, which has hitherto been a matter of difficulty;" and in the following autumn he wrote to his engineering friend Mr. John Farey, jun., "my machine is now undergoing one of its ultimate changes, and I expect very soon to have it completed."

Accordingly, in September of the same year, he wrote what appears to have been intended as the title and commencement of a specification of a patent for the invention. The title shows that the description stops short altogether of one of the two species of machines intended to be included in it; it is also obviously incomplete as to many particular proportions and movements of the several individual parts requisite for producing the desired effect. But of all of them, accurate drawings, beautifully made by himself, to a scale, remain; showing that the machines were not only completed in fact, and used in practice, but were also carefully delineated by him, with a view, no doubt, to the relative drawings proper to be attached to such a specification, when delivered in at the Patent Office. The invention having been thus fully completed, and having also been publicly used by Mr. Watt in making the frequent copies of various specimens of sculpture which he, from time to time, distributed to his friends, operated, in more than one instance, to prevent patents being subsequently taken out by others for similar ingenious machines.

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* 7th December, 1812.

The following is the fragmentary description to which we allude, and which is dated September 21st, 1814:—

"Certain new methods, machines, tools, and processes, by means of which copies, duplicates, or imitations are or may be executed, cut, carved, or made from the originals, casts, or models of statues, busts, medallions, seals, dies, moulds, mouldings, and other carvings, bent, waving, and uneven surfaces, in or upon some sorts of metal, ivory, bone, horn, tortoise-shell, wood, marble, and certain other stones and other substances; so that the said copies are or shall be of the same, or of some greater or lesser size than the said originals, within certain limits as may be desired.

"The said machines are of two kinds: First, those which are intended to form copies of lesser or greater dimensions than the originals or patterns; and secondly, those which are intended to form copies of the same size as the originals or patterns.

"I begin with the first kind, as being the most simple in their construction. They consist of a bar, beam, or radius, having one universal joint or other centre-piece, at one end, which permits the other end to be moved in any direction, but will not permit the said bar or beam to turn upon its own axis in any sensible degree. This beam is connected by the said joint with one end of an oblong platform, upon which are guided two tablets in such manner that they can be slid to and from the centre without lateral shake. Upon the said beam are fixed two sockets, each carrying a point perpendicular to the surface of the said tablets; and the distance of these points from the centre of motion of the beam is proportioned to the difference of size which is intended to be made between the patterns and the copy, so that when the one point called the guide, (which must be more or less blunted,) is drawn backwards and forwards upon the pattern, (which is fixed upon one of the tablets,) the other point, which is sharp or cutting, may cut or form a line upon the block or substance to be operated upon, which is fixed upon the other tablet, similar in its elevations and depressions to the line traced by the guide-point."

On one of the drawings Mr. W. has written "This pantograph will serve to reduce to $\frac{1}{2}$, $\frac{1}{4}$, and $\frac{1}{8}$. A similar one will reduce to $\frac{1}{3}$ and $\frac{1}{6}$; $\frac{1}{5}$ and $\frac{1}{7}$ are not so useful, and may be omitted."*

On the backs of letters there remain some notes made by Mr. Watt, of the time occupied by him on several days in succession in making copies of busts with the diminishing machine: one specimen of such rough journals we give here, as indicating the various steps of the process and the comparative time occupied in each. The result was a beautiful head, in alabaster, which still exists in the possession of Mr. Watt's representatives; but it was done before the attainment of all the facility with which some later improvements of the machine enabled the operator to work, and which gave greater rapidity of execution:—

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* We have also found, in Mr. Watt's handwriting, the following recipes for a "Cement for hardening plaster patterns for the carving machine," of date Nov. 1st, 1810:—

"1. Wax $^3/_4$ oz., black rosin 2 oz.; melt together by a gentle heat.

"2. Wax 1 oz., red-lead or litharge 1 drachm, rosin 2 oz.; dissolve the red-lead in the wax by boiling them till effervescence ceases, then add the rosin, and, when melted, withdraw from the fire.

"Wax 1 oz., sulphur 1 drachm; unite them by a strong heat, and then add 2 oz. rosin at a lower heat.

"The cement No. 1 melts very fluid at a low heat, and will do very well for subjects where small guide-points are not necessary.

"Where small points are necessary, No. 2 or No. 3 should be used; but they do not run so thin, and require more heat to melt them, especially No. 2.

"To use these cements, let the plaster pattern be made sufficiently hot, by placing it before the fire, or in an oven or stove; then anoint it with the cement by a brush, and expose it before the fire, or in a stove, until it absorbs the cement. Give it in the same manner a second, third, or even fourth coat, until it has penetrated at least $^1/_4$ inch into the plaster; remove it from the fire before it has totally absorbed the last coat, which it will take in while it cools; and any which does not seem likely to be absorbed must be wiped off by a rag or some tow, and the pattern laid in a cool place."

This is followed by a "Cement to fasten the patterns to be cut, to the tablet of the machine. Wax and rosin equal parts, say 2 oz. of each, and, to prevent it cracking in cold weather, add $^1/_4$ oz. of a mixture of 3 parts linseed oil and 1 part of wax, boiled together until when cold they become solid."

Bust of Sappho, January, 1811.

		Hour
“Jan. 28.	Making pedestal, 1 hour	1
29.	Soaking in a strong coat of oil-varnish, and cementing the bust on pedestal	1
30.	Cutting out the stone, cementing it and the bust to the moveable plates, and fixing the centres	3
31.	Roughing the stone with the tearing-drills to within the thickness of a halfpenny of the truth	9
“Feb. 1.	Going over it with the quarter-inch drill to within the thickness of a thin sixpence	5
“Saturday 2.	Doing the face with the $^1/_8$ drill to the truth, from the outer corner of one eye to do. of the other (went too slow)	5
3.	Doing her best with do.	1
“Monday. 4.	Do. one side of the head	4
“Tuesday. 5.	Do. round to within $^1/_4$th of the whole	4
6.	Quite round, finished the shoulders, removed some of the steps, or plaits	3
7.	Cut the crown of the head, undercut the neck, and cut it off from the centre-piece, repaired the most of it	3
		39

In 1816, the machine underwent some further improvements, “to assure steadiness in its working,” but in August, 1817, Mr. Watt feeling “very languid and unfit for exertion of any kind,” and also experiencing “an occasional dimness of sight, which rendered it at times difficult for him to write even with spectacles,” deferred his superintendence of further changes which were to be made on it, till his return from his tour in Scotland. Some later notices that we have of it from his hand are interesting ones; for in the end of 1817 we find him writing to his friend Chantrey, then near the summit of his fame as the first of British sculptors, “the diminishing machine is made ready for the trial;” Chantrey replied in the following March, expressing the great desire he felt, from the report Mr. Rennie had made to him, to examine the machine; and offering a visit to Heathfield for that purpose in June "if you will be kind enough to encourage me with a promise that I shall then see it." The desired invitation was duly sent; but when Chantrey next passed through Birmingham, (on his return from Scotland in 1818), it unfortunately happened that Mr. Watt was absent from home, and the great sculptor's curiosity therefore remained unsatisfied. The last drawings which Mr. Watt made of any portions of the machine are dated by him February and April, 1818. But it does not appear that, in the last year of his life, he did much more to or with it.

The classical "garret" and all its mysterious contents,—the Polyglyptic Parallel-Eidograph with its tools and models included,—have ever since been carefully preserved in the same order as when the hand and "eye of the master" were last withdrawn from them, and he crossed the threshold never to return to his work on earth. When last inspected by us, (in 1853,) all things there seemed still to breathe of the spirit that once gave them life and energy; and only the presence of some reverend dust silently announced, that no profane hand, forgetful of the "*religio loci*," had been permitted to violate the sanctities of that magical retreat, or disturb the repose of the "wheels," and "drills," and "guiding-points," that have never since been moved.

CHAPTER XXVII.

MR. WATT'S PURSUITS IN RETIREMENT—SECOND JOURNEY TO PARIS—PURCHASES OF LAND IN WALES—THE SNUFF-BOX—EVENINGS AT HOME—SHRIEVALTY OF STAFFORDSHIRE AND RADNORSHIRE—STUDY OF ANGLO-SAXON—POLITICAL SENTIMENTS—ANECDOTES OF HIS SON JAMES—CHARACTERISTICS OF MR. WATT'S CONVERSATION AND FRIENDLY COUNSELS—REVISAL OF ROBISON 'ON STEAM'—EDGEWORTH'S PROPOSAL OF A TUNNEL ACROSS THE MENAI STRAIT.

SUCH were some of the mechanical recreations in which the aged engineer was wont to employ the moderate strength, and the unalterably inventive thoughts, which were still granted to him; blending with them, when at home, the pleasures of horticulture, of happy social intercourse with his neighbours, of most various study, and even of *novel-reading*,—with him always a favourite department of literature!

About the middle of his life, he caused to be engraved on one of his seals, a human eye, with the motto "OBSERVARE;" and to that significant device he ever remained true. When he occasionally visited London, he lost no opportunity of making himself practically acquainted with every new discovery or contrivance of merit, of which any report had reached him: on the ingenious wonders so abundantly exhibited in the shop-windows and warehouses of the metropolis, he gazed with all the delight of a child; and it often happened that their owners, after leading him into conversation, and finding themselves far surpassed in knowlege of their own peculiar pursuits, felt as though they had "entertained an angel unawares." The orbit of his movements, in short, always bright with his own light, was also marked, long after the period of his passage, by what M. Arago has so characteristically termed "luminous traces."

Sometimes, during the last quarter of a century of his life, he gave to his journeys a somewhat wider geographical range. In 1802, when, during the peace of Amiens, the Continent was for a brief season opened to British travellers, he once more visited Paris; where he renewed his acquaintance with those of his former scientific friends whom time, and the crimes of the revolution, had spared. "We were very kindly received," he writes to Professor Robison,* "by my old friends at Paris, M. Berthollet, M. Monge, and M. de la Place, now become Senators. M. Prony and M. Hassenfratz were also exceedingly attentive; the former especially, and seems an exceeding good sort of a man, as well as a very able mathematician. He appeared to be sorry that he had not taken more notice of me in his book on the steam-engine, and has offered to publish, in a succeeding volume, anything I please to furnish him with on the subject. Many others were very kind. We passed five weeks there, and, had the weather been warmer, I should have wished to prolong my stay." * * To the great men of science here named, and the Abbé Haüy, whom he elsewhere includes in the list, must be added another,—perhaps the most interesting of all,—Benjamin Delessert;—a name sacred to the cause of science, of art, and of philanthropy. See his interesting 'Eloge Historique' by M. Flourens, ('Hist. de l'Acad. des Sciences,' tome xxii. p. cxix.–cxliii.); where it is said—"Benjamin Delessert passa à Birmingham. * * Le génie de la mécanique y soumettait à l'homme l'une des forces les plus puissantes et les plus terribles de la nature. Benjamin Delessert fut témoin des essais de Watt. * * Chacun de ces hommes célèbres, comme ces Fées bienfaisantes qu'avait rêvées l'imagination, de nos pères, doua Benjamin Delessert d'un talent particulier. * * Watt le doua de l'intelligence supérieure des arts mécan-

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* 26th April, 1803.

iques." In the pursuit of learning and taste, M. Delessert possessed, as all his friends will long remember, multiplied endowments of no less value than that which he thus received at the hand of James Watt. But it is still more worthy of notice, that his path was that of the just, and his death that of the righteous. The secret of his virtuous life was, at its close in 1847, revealed in these words, made public with his last testament,—(one full of charitable forethought, and munificent care for his fellow-men,)—" Après une bonne action, on éprouve un sentiment de bonheur qui est au-dessus de toute idée: on dort d'un sommeil paisible, et tous les songes sont agréables!"

We cannot resist the temptation of here inserting a letter which, after his return home, Mr. Watt received from another of his foreign friends, and which speaks with a natural eloquence that must have been irresistible.

" Offenbach, near Francfort, the 4 of March, 1803.

"Much honored Worthy Sir,—would your Genius have read in my Soul, the very moment I perused the obliging letter with which you honored the old mother of Sophy Sternheim, be sure I remembered with blessing the hour I saw in my little abode *Sir James Watt,* the great benefactor of all Centuries to come,—having proved the power of a mind, Who surely and steadily aply'd his faculties, for the improvements of Science and Art—the more useful, for his fellow creatures—Physik and Mecanik—will for ever bless your name—I was happy to behold you with a New Conviction, *that the very great man is a very good man*—I admire you for the first, but bless and love you for the second.—May your Sons partake, of your Spirit, and character, with wath feelings, should I have seen the worthy mother of your Childs—and I will ever regret her sikness—and my old age who has deprived me of the advantage to become acquainted to her.—I have thanked my god, to shaked the hand, who has traced the perfection of Steam Engine—and I pray god, to conserve you Mistriss Watt and family—in all happiness, far more, than 73 years of mine. When Dear Sir! you recall Germany, say that. you have there an old friend and well-wisher in

"SOPHY LA ROCHE."

"excuse Dear Worthy sir! all the faults, of the broken Englisch, I was bold enouhg to write you. Mister Trapp, has my everlasting thank for the blessing hour, in wich He conducted you to my cottage.—*God bless you.*" *

Mr. Watt also frequently amused himself with tours of observation and enjoyment throughout England, Scotland, and Wales; as well as with agricultural pursuits, and various rural improvements, on some farms in the latter country, which the beauty of the scenery, uniting the softness of the south with some of the wild grandeur of the north, induced him to purchase. He began that species of investment in 1798, on a small scale; and some of the parcels of land which he at first bought were rather widely scattered; but many of them, with large additions made by his son, now form a very extensive estate, the greater portion of which is situated in Breconshire and Radnorshire, between Rhayader and Newbridge, on the most charming part of the course of

"The sylvan Wye, that wanderer through the woods,"

and of the Ithon, one of the most picturesque of its tributaries.

The simple, but neat and comfortable farmhouse of Doldowlod, (of which a portion yet remains, although now overtopped by another mansion, of greater pretension, lately erected by its side, and communicating with the more modest cottage of earlier days,) was the home which congenially received him on his occasional visits. The fine woods which there richly clothe the valley, and agreeably diversify the river and mountain scenery, were chiefly planted under his superintendence and direction;—very many of the trees by his own hand.

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* This quaint epistle is given exactly as it was sent, unaltered in one jot or tittle of its charming *naïveté*. The good old lady who penned it was the authoress of the 'History of Lady Sophia Sternheim,' (translated by J. Collyer, 2 vols., 1776); and also of a Journal of Travels in Holland and England, ('Tagebuch einer Reise durch Holland u. England, von Sophie Wittwe von La Roche;' Offenbach am Main, 1791). We trust that God "conserved" in all peace to the end of her days her honest, ardent, German heart; which united to such admiration of intellectual greatness, the emotions of humble, pious goodness.

In all that concerned the acquisition and beneficial management of their Welsh property, both Mr. Watt and his son derived very material aid from the enlightened judgment and great ability of the late Mr. James Davies, of Moorcourt in Herefordshire; a gentleman whose services to his own and two neighbouring counties were sensibly felt and splendidly acknowledged by their inhabitants. His good memory, indeed, can scarcely fail to descend to posterity along with that of John Kyrle, "the man of Ross," whose career of active usefulness, (although their tastes were in some respects different,) he may be said to have successfully emulated. Mr. Davies died in 1856, aged 78, full of years and of rural honours.

In the happy microcosm in which the great inventor thus lived, "his mind to him a kingdom was;" and his peaceful pursuits were seldom interrupted by any perturbation from without. His first occupation on returning home from any absence, was to walk round his garden, followed by his gardener, surveying his fruit-trees, and commenting on their progress and produce; admiring their blossoms, or examining those fruits, in whose gradual ripening and fall, the wise can trace a natural image of their own maturity and decay." *

If fond of flowers, it must also be confessed that he was not without a secret relish for a certain fragrant weed; and that, too, as prepared in one of its forms now perhaps least fashionable: in other words, he greatly enjoyed the homely solace of an occasional pinch of snuff. This predilection, however, was rarely indulged; as the assiduous legislation of Mrs. Watt denounced the snuff-

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* "Et quasi poma, ex arboribus, si cruda sunt, vi avelluntur; si matura et cocta, decidunt; sic vitam adolescentibus vis aufert, senibus maturitas."—Cic. 'De Senectute,' cap. xix.

box. Her habit was to lay violent hands on the offending "mull," wherever she could surprise it, and to carry it away to the safe custody of her china-closet. The philosopher submitted, with his usual placidity; but again, in his own good time, was sure to watch the dame when employed amid her favourite ware, and, while her back was turned, to steal a pinch; or even to recapture the box, and bear off his prize in triumph.

> "Still, as he ran, he look'd behind,—
> He heard a voice in every wind,
> And snatch'd a fearful joy!"

In his "evenings at home," at a certain hour, *fixed by Mrs. Watt*, the door of the dining-room in which she had all too lately left her lord, opened: an old servant appeared, and, altogether disregarding the greater presence in which he stood, with a few active evolutions swept out at once the fire, the lights, and—his master! Adieu, the social *tête-à-tête;* adieu, the book, or soothing reverie of the night; adieu,—some fainter hearts might have said,—to the pursuit of knowledge under such difficulties! But we have it from one who witnessed some of those untimely irruptions, that, as the host slowly rose, he was wont to say with meekness, "*We must go;*"—that still the quiet smile never quitted that benignant countenance,—the serenity of that sweet temper remained undisturbed.

"His habit was, immediately on rising, to answer all letters requiring attention; then, after breakfast, to proceed into the workshop adjoining his bedroom, attired in his woollen surtout, his leather apron, and the rustic hat which he had worn some forty years, and there go on with his [sculpture] machine." * So says a writer who doubtless borrowed his information from a source that he thought might be safely relied on; but the first portion of this statement may be questioned. For, in opposition to the received maxims of longevity, as well as to the doctrine of Dante, who says that—

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* 'Quarterly Review,' vol. CIV. p. 450. 1858.

———"not
On downy plumes reposing, fame is won,"

Mr. Watt was not a very early riser; and, on many days of his life, the letters that he wrote, would, as we have already mentioned, "alone have furnished full employment even to an industrious intellect." "The mental fatigue of Mr. Watt," says Mrs. Schimmel Penninck, "was often so great, that I have heard he required from nine to eleven hours' sleep to recruit his powers, and his evenings were uniformly spent in some light amusing reading." "He seldom rose very early," says his cousin Mrs. Campbell, "but accomplished more in a few hours' study than ordinary minds do in many days." *

Twice, a summons to undertake the burdensome honour of the Shrievalty, (of Staffordshire in 1803, and again of Radnorshire in 1816,) was met by Mr. Watt with uneasy apprehension, and repulsed with all his energy. At that time he thus almost plaintively stated his own case, with a view, as he says, of "averting so serious a misfortune as serving that office" would have been to him: †—"I am nearly seventy years old; my health, always precarious, generally confines me to the house for the greatest part of the winter and spring. I never was endowed with the speedy decision, firmness of character, and intrepidity necessary for a public station, and these qualities have not been augmented by my declining years. You, as well as any man, know the anxiety and vexation which I endured for many years from the harassing lawsuits in which we were unfortunately engaged, and which have had the effect of making me very unfit for business of any kind; the powers of my mind are worn out, as well as those of my body. I have laboured very hard for the public during the greater part of my life, and hope I have been

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* See above, p. 24.

† To Mr. A. Weston, 15th November, 1803.

of some use. Though I cannot bring forward to the public mind the 'labores, sudores, vigilias,' yet the 'instrumenta artis nostræ' are in everybody's hands. I have been useful to the State in the way Nature intended, and hope I shall not have a duty imposed upon me I am totally unfit for, nor have my grey hairs weighed down by a load of vexatious cares. You know that from my inability to support the cares of business I have retired from it with a very moderate fortune, in order to enjoy that quiet for which alone I am now fitted, and which I pray may be undisturbed. My property in the county is very small,—only a house and forty acres of poor land, which has *any* value only from its vicinity to Birmingham.

"The present juncture of affairs seems to require a Sheriff in the prime of life, possessed of activity and decision, and not a timid old man. It is not my part to say who is equal to the office; but I am fully impressed with a sense of my own unfitness, and hope I have not deserved so ill of the nation as to be placed in a situation that might expose my weakness, or perhaps have worse consequences."

Although every exertion was used by those to whom Mr. Watt communicated his wishes on this occasion, there was at first a great deal of difficulty in getting him excused from serving in the office to which he had been nominated. But Mr. W.'s scientific friends, Sir Joseph Banks and the Hon. C. Greville, having used their influence with his Grace the Duke of Portland, then President of the Council, that nobleman, in the most kind and handsome terms, expressed his opinion that Mr. Watt's disposition to preserve that quiet to which he was so well entitled would induce the members of the Council to direct his name to be removed from the list of persons nominated as sheriff.

In 1816, the circumstances were nearly the same; with the additional weight which his completion of fourscore years had given to the argument arising from declining strength; and no difficulty seems to have been found in granting the prayer for exemption uttered by what has been beautifully called "the voice of age resistless in its feebleness."

"My reasons against serving," he then writes to Mr. Robert Muirheid,* "are, that I have nearly completed my 81st year, have precarious health, and am generally confined to the house all the winter and spring; that I have spent a long life in improving the arts and manufactures of the nation; my inventions at present, or lately, giving employment to [the] best part of a million of people, and having added many millions to the national riches, and therefore I have a natural right to rest in my extreme age; that I have no domicile in the country, nor ever had, and have not been in it more than two years, and probably never shall; that for these reasons I was excused serving for the county of Stafford, in which I live, twelve years ago, and some of them should weigh more now. Eighty-one is not a period of active life, and, as far as my personal qualities are concerned, I esteem myself perfectly unfit; and the consequences of serving would probably be the sending me a year or two sooner to the grave."

His apprehensions that the powers of his mind had been worn out, happily remained groundless till the hour of his death. It has been recorded of Dr. Samuel Johnson, in a work which none can read without receiving instruction, and few without experiencing delight, that in the latter part of his life, in order to satisfy himself whether his mental faculties were impaired, he resolved that he would try to learn a new language. For that purpose, he fixed upon the Low Dutch, and continued his application until he had read about one half of Thomas à Kempis in that unattractive tongue; and, finding that there appeared no abatement of his power of acquisition, he then desisted, satisfied that the experiment had been duly tried.† At a similar period of life, and with a similar view, Mr. Watt resolved to prosecute a like investigation; the language he chose was Anglo-Saxon, and the result was perfectly satisfactory to his mind.

It is right that we should here authoritatively vindicate the venerable subject of our biography from the allegation,—which, however, in these days of rapid political conversion it might be somewhat unsafe to call the *reproach*,—of having been what is termed "a sad radical." There never was a more unfounded impression formed of any man's political sentiments than this; for the wise engineer was throughout his life possessed with the most loyal and constitutional principles; having been, in truth, a plain and homely, but honest and steady *Tory*, of what is called, not without strong reason, and by way of contrast, we suppose, to some modern innovations, the good old *consistent* school. "Our principles," he says, when describing the riots at Birmingham in 1791, and the threats held out by the mob, "which are well known as friends to the established government and enemies to republican principles, should have been our protection from a mob whose watch-word was *Church and King;*" and he uniformly expressed his horror at the proceedings of the revolutionists in France, as well as of the unbridled sovereignty of the peeple in any country. So clear and decided, indeed, were his convictions on such matters, that we should scarcely have thought it necessary to allude to them, had it not been that a prime minister of England was understood to have given utterance, previous to the close of Mr. Watt's life, to the erroneous doctrine already referred to; and we have ourselves, in the present day, heard the same creed repeated by a very able and usually most accurate person, who, however, was on this point no better informed than the Earl of Liverpool had been.

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* 23rd November, 1816.

† See Langton's Reminiscences, in 'Boswell's Life of Johnson,' vol. iv. p. 17, ed. Oxford, 1826.

The truth is, that both of those gentlemen, and any others who may have shared their opinion on this subject, led astray by the similarity of name, have confounded Mr. Watt as a politician, with his son Mr. James Watt; who certainly was in his youth carried away, by the enthusiasm then prevalent in what was termed the cause of liberty, to sympathise with the Girondins and Jacobins in Paris, and even to take some open and avowed part in their earlier tumultuous agitations. He was for some time, in company with Thomas Cooper, and Wordsworth the poet, in the habit of associating with many of those men who afterwards attained a dreadful celebrity; and, as Southey has mentioned, was at that time the means (unfortunately for the world!) of preventing a duel between Danton and Robespierre.

"Danton and Robespierre," says Southey, "quarrelled at one of the political clubs, before the 10th of August: high words ended in a challenge: they met, and the duel was prevented by the interference of an Englishman, who went out as a second to the one, and represented to them how injurious it would be to the cause of liberty if either of them should fall. (!) That Englishman was the present James Watt of Soho, and from him I heard this remarkable fact."*

For another more public exhibition of mistaken zeal displayed in the same cause, Mr. James Watt, jun., and his clever, but eccentric friend Cooper, were thus severely denounced in the British House of Commons;—"Messrs. Cooper and Watt," said Burke, in the debate on Mr. Sheridan's motion relative to the existence of seditious practices in this country,† "had presented an address, and carried the British colours in a procession; and on what occasion? The most infamous that ever disgraced the name of government. A set of soldiers had been tried by a court-martial, and condemned to the galleys. These were fit men for the republicans of Paris. They might be useful:—though bad soldiers, they might be good murderers. They were released in contempt of the Assembly then sitting; brought to Paris, and paraded in triumph through the hall. On this detestable occasion, Mr. Cooper and Mr. Watt carried the British colours. They were locked in the fraternizing embrace. They received the fraternizing kiss. They went from the hall of the Assembly to the hall of the Jacobins, where they kissed the bloody cheek of Marat;—the iron cheek of Pluto instead of Proserpine;—

> "What ardent transports through their bosom ran,
> Clasp'd in the embraces of the godlike man!" ‡

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* See letter from Southey to A. Alison, Esq., (now Sir Archibald Alison, Bart.), Keswick, April 17, 1833. 'Life of R. Southey,' by Rev. C. C. Southey, vol. vi. p. 209.

† March 4, 1793.

‡ Speeches of the Right Hon. Edmund Burke, vol. iv., p. 124, ed. 1816.

The first blood of citizens, however, which the young political enthusiast saw spilt in the gardens of the Tuileries and streets of Paris, sickened him of that "licence" which those wretches meant "when they cried liberty;" and he then endeavoured to mitigate as far as possible that violence of revolutionary rage which he foresaw he must in future deplore.

This partial change of sentiment led to a curious result; for Robespierre having then insinuated in one of his addresses at the Club of the Jacobins, that Cooper and his compatriot were emissaries of Pitt, Mr. J. Watt, with the same fearlessness with which he had previously supported a cause which he imagined to be just, took an instant opportunity of confronting that monster in his own arena;—he indignantly sprang on the tribune, from which by main force he ejected the truculent orator, and in a brief but impassioned harangue, delivered in French, which he spoke with perfect fluency and an excellent accent, completely silenced his formidable antagonist, carrying with him the feelings of the rest of the audience, who expressed their sense of his honest British spirit, in a loud burst of applause! On returning home, having learned, by sure intelligence from one deep in the secrets of his dangerous foe, that his life was no longer safe for a day, he instantly quitted Paris, without even a passport. He succeeded, though with some difficulty, and occasionally at great hazard, in making his way to the south, and never rested till he arrived in Italy. There having devoted himself to other pursuits than politics, and his revolutionary ardour having had time to cool, he saw good cause to shudder at the atrocities committed by those who so lately had been his chosen companions.

"I went over to Paris,"—said the late poet Wordsworth to us, in one of those hours which his presence and converse winged with unfailing delight,—"at the time of the revolution in 1792 or 1793, and so was *pretty hot in it;* but I found Mr. J. Watt there before me, and *quite* as warm in the same cause. We thus both began life as ardent and thoughtless radicals; but we have both become, in the course of our lives, *as all sensible men, I think, have done,* good, soberminded Conservatives!"

Such, however, is no doubt the true explanation of the politics of Mr. Watt, senior, having ever been mistaken. But although his own views were uniformly such as we have stated, even he, in judging those of others who differed from himself, seems to have exhibited all that philosophical moderation which so strikingly characterised his habitual sentiments: as when speaking of Professor Robison he says,—"he entertained a high respect for the constitution of his country, and detested the novel doctrines of Jacobinism, which made him pass *censures too severe upon several of the French philosophers, (otherwise extremely estimable men, and to whom science is much indebted,) without duly weighing the circumstances in which they were placed.*"

In the winter of 1813–14, he complied with the request of his distinguished friend, Sir David Brewster, in looking over the articles 'Steam,' and 'Steam Engines,' written by Dr. Robison, for an edition of Dr. R.'s collected works; and he then added to them, with considerable labour, his valuable and well-known annotations as to his own inventions and improvements. His MS. he accompanied by the following interesting letter to Sir David, in which he accurately discriminates between the apparent meaning of some rather obscure expressions that Dr. Robison had used, and that which no doubt they had been intended to bear.

Heathfield, May, 1814.*

"Dear Sir,—At your request, I have carefully perused my late excellent friend Dr. Robison's articles 'Steam' and 'Steam-engines' in the 'Encyclopædia Britannica,' and have made remarks upon them in such places where, either from the want of proper information, or from too great a reliance on the powers of his extraordinary memory, at a period when it probably had been weakened by a long state of acute pain, and by the remedies to which he was obliged to have recourse, he had been led into mistakes in regard to facts; and also in some places where his deductions have appeared to me to be erroneous.

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* Robison's 'Essays on Mechanical Philosophy,' edited by Sir David Brewster.

"There had been but very little interchange of letters between us for some years previous to his writing those articles, and our opportunities of meeting had been rare and of short duration, and not occupied by philosophical discussions. Had I been apprized of his design, I might at least have prevented the errors respecting the facts in which I was concerned; but, upon the whole, it is more surprising to me that his recollection should have served him so well in narrating transactions of 30 years' standing, than that it should sometimes have led him astray. If I had not retained some memorandums made at the time of, or soon after, their occurrence, I should myself have felt great difficulty in recalling to mind the particulars at the period when I first perused those articles, which was some time after their publication. I had about that period an opportunity of personally stating to Dr. Robison some remarks upon them, of which he availed himself to a small extent in the Supplement to the 'Encyclopædia Britannica,' and probably would have done so still more, had he been called upon to remould those articles.

"I have endeavoured to throw most of my corrections into the form of notes; but in some places I judged it necessary to alter the text, which alterations I have marked to be printed in italics, that they may be readily distinguished from the original. In a few places, I have cancelled part of the text without any substitution, none appearing to me to be required. In others, I have left part of the reasoning unaltered which I did not concur in; as in mere matters of opinion, where no manifest error was involved, I did not conceive it proper to introduce my own speculations.

"As the subjects of steam and steam-engines had been almost dismissed from my mind for many years previous to my undertaking this revision, I have called in the aid of my friend Mr. Southern, and of my son, whose daily avocations in the manufacture of steam-engines render them more conversant with some points, to direct my attention to them; and of the former, to examine such of the algebraic formulæ as appeared essential,—an office for which he is much better qualified than myself; and he has accordingly marked those formulæ with his initials.

"I have not attempted to render Dr. Robison's memoir a complete history of the steam-engine, nor have I even given a *detailed* account of my own improvements upon it. The former would have been an undertaking beyond my present powers, and the latter must much have exceeded the limits of a commentary upon my friend's work. I have, therefore, confined myself to correcting such parts as appeared necessary, and to adding such matter as he had not an opportunity of knowing.

"Here it was my intention to have closed this letter, but the representations of friends whose opinions I highly value, induce me to avail myself of this opportunity of noticing an error into which not only Dr. Robison, but apparently also Dr. Black has fallen, in relation to *the origin* of my improvements upon the steam-engine; and which, not having been publicly controverted by me, has, I am informed, been adopted by almost every subsequent writer upon the subject of Latent Heat.

"Dr. Robison, in the article 'Steam-engine,' after passing an encomium upon me, dictated by the partiality of friendship, qualifies me as the '*pupil* and intimate friend of Dr. Black;' a description which, not being there accompanied with any inference, did not particularly strike me at the time of its first perusal. He afterwards, in the dedication to me of his edition of Dr. Black's 'Lectures upon Chemistry,' goes the length of supposing me to have professed to owe my improvements upon the steam-engine to the instructions and information I had received from that gentleman, which certainly was a misapprehension; as, although I have always felt and acknowledged my obligations to him for the information I had received from his conversation, and particularly for the knowledge of the doctrine of latent heat, I never did, nor *could*, consider my improvements as originating in those communications. He is also mistaken in his assertion, (p. 8 of the Preface to the above work), that 'I had attended two courses of the Doctor's lectures;'* for, unfortunately for me, the necessary avocations of my business prevented me from attending his or any other lectures at College; and as Dr. Robison was himself absent from Scotland for four years at the period referred to, he must have been misled by erroneous information. In page 184 of the Lectures, Dr. Black says, 'I have the pleasure of thinking that the knowledge we have acquired concerning the nature of elastic vapour, in consequence of my fortunate observation of what happens in its formation and condensation, has contributed in no inconsiderable degree to the public good, by *suggesting* to my friend, Mr. Watt of Birmingham, then of Glasgow, his improvement on this useful engine,' (meaning the steam-engine, of which he is then speaking.) There can be no doubt, from what follows in his description of the engine, and from the very honourable mention which he has made of me in various parts of his lectures, that he did not mean to lessen any merit that might attach to me as an inventor; but, on the contrary, he always was disposed to give me fully as much praise as I deserved. And were that otherwise doubtful, it would, I think, be evident from the following quotation from a letter of his to me, dated 13th February, 1783, where, speaking of an intended publication by a friend of mine on subjects connected with the history of steam, he says, 'I think it is very proper for you to give him a short account of your discoveries and speculations, and *particularly to assert clearly and fully your sole right to the honor of the steam-engine.*'†

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* "Repeated more in detail, with the same erroneous inferences, in his Note, vol. i. p. 504.—(J. W.)"

† See a more full extract from the letter in question printed at p. 15 of Mr. Watt's corrrspondence on his 'Discovery of the composition of Water,' 1846. It is the same letter in which Dr. Black, speaking of Mr. Watt's discoveries, says, "were you to be the first publisher of them yourself, you would do it in such a cold and modest manner, that blockheads would conclude there was nothing in it, and rogues would afterwards, by making trifling variations, vamp off the greater part of it as their own, and assume the whole merit to themselves." Those prophetic sayings were, singularly enough, almost immediately followed by what Robison calls the "*tracasserie*" of Cavendish and Blagden.

And in a written testimonial which he very kindly gave on the occasion of a trial at law against a piracy of my invention in 1796–7, after giving a short account of the invention, he adds, '*Mr. Watt was the sole inventor of the capital improvement and contrivance above-mentioned.*'

"Under this conviction of his candour and friendship, it is very painful to me to controvert any assertion or opinion of my revered friend; yet in the present case I find it necessary to say, that he appears to me to have fallen into an error; and I hope, in addition to my assertion, to make that appear by the short history I have given of my invention in my notes upon Dr. Robison's essay, as well as by the following account of the state of my knowledge previous to my receiving any explanation of the doctrine of Latent Heat, and also from that of the facts which principally guided me in the invention.

"It was known very long before my time, that steam was condensed by coming into contact with cold bodies, and that it communicated heat to them. Witness the common still, &c., &c.

"It was known by some experiments of Dr. Cullen and others, that water and other liquids boiled *in vacuo* at very low heats:—water [at] below 100°.

"It was known to some philosophers, that the capacity, or *equilibrium* of heat, as we then called it, was much smaller in mercury and tin than in water.

"It was also known, that evaporation caused the cooling of the evaporating liquid, and [of] bodies in contact with it.

"I had myself made experiments to determine the following facts:—

"1st. The capacities for heat of iron, copper, and some sorts of wood, comparatively with water. Similar experiments had also subsequently been made by Dr. Irvine on these and other metals.

"2nd. The bulk of steam, as compared with that of water.

"3rd. The quantity of water which could be evaporated in a certain boiler by a pound of coals.

"4th. The elasticities of steam at various temperatures greater than that of boiling water, and an approximation to the law which it followed at other temperatures.

"5th. How much water, in the form of steam, was required every stroke by a small Newcomen's engine, with a wooden cylinder 6 inches diameter, and 12 inches long in the stroke.

"6th. I had measured the quantity of cold water required in every stroke to condense the steam in that cylinder, so as to give it a working power of about 7 lbs. on the inch.

"Here I was at a loss to understand how so much cold water could be heated so much by so small a quantity in the form of steam, and [I] applied to Dr. Black, as is related in the short history, p. 116, note; and then first understood what was called Latent Heat.

"But this theory, though useful in determining the quantity of injection necessary where the quantity of water evaporated by the boiler, and used by the cylinder, was known, and in determining, by the quantity and heat of the hot water emitted by Newcomen's engines, the quantity of steam required to work them, did not lead to the improvements I afterwards made in the engine. These improvements proceeded upon the old-established fact, that steam was condensed by the contact of cold bodies, and the later known one, that water boiled *in vacuo* at heats below 100°, and, consequently, that a vacuum could not be obtained unless the cylinder and its contents were cooled, [at] every stroke, to below that heat.

"These, and the degree of knowledge I possessed of the elasticities of steam at various heats, were the principal things it was *necessary* for me to consider in contriving the new engine. They pointed out that, to avoid useless condensation, the vessel in which the steam acted upon the piston ought always to be as hot as the steam itself:—that to obtain a proper degree of exhaustion, the steam must be condensed in a separate vessel, which might be cooled to as low a degree as was necessary, without affecting the cylinder; and that, as the air and condensed water could not be blown out by the steam, as in Newcomen's, they must be extracted by a pump, or some other contrivance:—that, in order to prevent the necessity of using water to keep the piston air-tight, and also to prevent the air from cooling the cylinder during the descent of the piston, it was necessary to employ steam, to act upon the piston, in place of the atmosphere. Lastly, to prevent the cylinder from being cooled by the external air, it was proper to enclose it in a case containing steam, and again to enclose that in a case of wood, or of some other substance which transmitted heat slowly.

" Although Dr. Black's theory of latent heat did not *suggest* my improvements on the steam-engine, yet the knowledge upon various subjects, which he was pleased to communicate to me, and the correct modes of reasoning and of making experiments, of which he set me the example, certainly conduced very much to facilitate the progress of my inventions; and I still remember, with respect and gratitude, the notice he was pleased to take of me when I very little merited it, and which continued throughout his life.

" To Dr. Robison I am also bound to aknowledge my obligations for very much information and occasional assistance in my pursuits, and, above all, for his friendship, which ended only with his life; a friendship which induced him, when I was beset with an host of foes, to come to London in the depth of winter, and appear as a witness for me in a court of justice, whilst labouring under an excessively painful disorder, which ultimately deprived him of life. To the remembrance of that friendship is principally owing my taking upon myself the office of his commentator at my advanced age.

" May I request, Sir, that you and the public will permit that age to be my excuse for any errors I may have committed, and for any deficiencies in the performance of an office which at no period would have been congenial to my habits; and allow me to remain, with esteem,

"Dear Sir, your most obedient humble servant, JAMES WATT."

That the intellectual pleasure derived from the society and conversation of Mr. Watt was of the very highest order, the united testimony of his most intimate friends and associates sufficiently proves. "It was no wonder," as Robison observed of an earlier stage of his life, "that the attachment to Mr. Watt was strong, when persons of every taste and every pursuit found in him an inexhaustible fund of instruction and entertainment." Men of all ranks shared freely in the benefits of his counsels, as well as in the enjoyment of his cheerful cordiality: and alike to the humble artisan as to the aristocrat of rank and talent, the winged hours flew fast in listening to his words of wisdom, delivered in the guise of easy, social, unassuming converse. "I experienced much pleasure," says St. Fond, "in visiting Mr. Watt, whose extensive knowledge in chemistry and the arts rendered his conversation very interesting. His moral qualities, and the engaging manner in which he expressed his thoughts, daily increased my respect for him. * * Mr. Watt is a man of great conceptions. Nature has endowed him with a very vigorous mind, and to his other excellent qualities he joins the mildest and most prepossessing manners, which interest even at first sight."*

To the very close of his life, this light of his burned steadily and brightly;—he was constantly applied to by those,—(and their name was legion),—who either had invented, or imagined that they had invented, mechanical contrivances of any novelty or utility; and who naturally wished either to obtain the criticism of so experienced a judge, or to bespeak his favour and encouragement. With the greatest candour and most condescending kindness he took pains to caution such persons against their over-sanguine expectations, and also to explain to them some fundamental principles in mechanics, which they too often had overlooked; but which lay, perhaps, at the very threshold of their inquiries, and, if duly considered, might, by stopping their further progress in a particular direction, prevent much subsequent vexation and loss of both time and money.

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* 'Travels in England,' ed. 1799, vol. ii. pp. 341, 347.

Thus, to Mr. W. Mitchell, in 1800:—"I am favoured with your letter of the 5th, and am obliged to you for the intimations it contains, none of which, however, are new to me, or useful in their present form. To give my reasons would make a longer letter than I have time or health for at present. Rotative motions, on the principles of the first and second you describe, have been tried and abandoned many years ago. The third (the spiral) is not practicable as you have drawn it, and would be attended with considerable disadvantages in any way; (it can only make half a revolution for each stroke of the engine.) A more perfect application of that principle is contained in the specification of my patent in the year 1781. In respect of the fourth invention, we use no racks or toothed sectors now; they are bad things; the method we use is much preferable, (which you may see at any of our engines.) In general, no rotative motion will answer well that requires the piston to move with equal velocity in every part of the stroke, and a common crank is nearly the best which has been yet contrived, or, perhaps, may ever be. I do not by what I have said mean to discourage you from paying particular attention to the subject; your ideas are ingenious, and by further experience you may think upon better things. I thank you for your attention to me, and the deference you express to my opinion, and think it my duty to set you right in a matter which might lead you into fruitless and expensive experiments."

So also, to the Rev. W. J. Rees, in 1810, in answer to an announcement of "a machine, or rather engine, lately discovered by a friend, an ingenious clergyman of this county, that gives motion to itself, and can communicate motion with immense power to any machinery to which it may be applied; or which may be described as an engine generating perpetual motion, with as great a quantity of power as to supersede the necessity of all other expedients;" (!) he writes,—"I am favoured with your letter of the 15th instant. I have several years ago entirely withdrawn from business, and am now a very old man, so that I can be of no use to your friend as an associate or patron. * * I hope yourself and your friend will excuse my incredulity, but I have very long been satisfied that there can be no such thing on earth as a perpetual motion, generated in the machine itself, without the expenditure of some external power or cause of motion. All the known elements have, as I believe, been already applied to machinery, and you do not infer that your friend has discovered any new one. It is possible that he may be deceiving himself, and I would therefore recommend to him, before he proceeds further, to make a *working* model of his machine, on as large a scale as he can, and from it to calculate the power and the probable expense of exciting it, and not to take any other steps in the business until he is satisfied he is in no mistake. * *

"I should have very great reluctance to be made the depositary of the secret of any invention which is not secured by patent. Should the invention not meet my approbation, it would lay me under the disagreeable necessity of speaking my sentiments upon it, which might be construed as dictated by interested motives; or, if the secret got abroad by other means, I might be blamed for it. Yet, on the other hand, the inventor might be benefited by my advice, the fruit of fifty years' experience in mechanics. On the whole, I wish to decline the confidence; but if I can give any useful advice, without a full confidence, I shall be glad to be of use to any ingenious man. If your friend will answer me by letter the following questions, it may save him the coming here, should he, after what I have said, think that proper. Is there no expenditure of any power or agent extraneous to the machine itself? and, if so, what may be the expense in money to enable the machine to raise 30,000 cubic feet of water 1 foot high? Is that extraneous agent any of the known powers or elements which have been employed to raise water, or give motion to machines, such as fire, water, steam, air, or animal force? Is the machine itself complicated or expensive? I feel myself very much obliged by the confidence which you have been pleased to repose in me, and shall endeavour always to merit your good opinion."

To the extravagant vagaries which occasionally were suggested to him by such projectors, there really were no limits; as when one author, in forwarding to him what he calls his "book on philosophy," observed:—"If the popular or Newtonian system of causes of mundane phenomena and motions are facts, and things are actuated by them as principles, I really am not constituted to hear, see, feel, or comprehend like other persons." A conclusion of the learned writer, the justice of which, (although not exactly in the sense in which he intended it,) probably none of our readers will be disposed to deny!

Of another project that was submitted to him about the same time as the clerical engine generating perpetual motion, which was to supersede all other expedients, we must speak with far greater respect. This was Mr. R. L. Edgeworth's idea of making a cast-iron tunnel across the Menai Strait, instead of the plan Mr. Rennie had then proposed of a bridge. "Our old friend," [Mr. Edgeworth,] says Mr. Keir in December, 1810, referring to this subject, "rides his hobby-horse (Mechanics, &c.) with the same spirit that he did forty years ago." "My scheme is," says Mr. Edgeworth,* "to join the parts of my fourteen-feet cast-iron cylinders in one curve, in a dry dock opening into the Menai; when the joints were sufficiently secured, the whole—let the length be what it might—would float when both its mouths were above water. When properly ballasted, I would open the floodgates of the dock, tow the tunnel into the river near the junction of the opposing tides, and sink it upon a bed, previously constructed, by large stones thrown into the water, so as to form two walls 16 feet asunder, filled with sand thrown between them, and supported by a talus of large stones extending to a considerable distance on each side of the walls. I do not suppose that these walls would, at an average, exceed 5 feet high. Secondly;—

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* To Mr. Watt, 6th January, 1811.

There is sufficient depth for vessels to pass over such a tunnel during neap-tides. Lastly;—I do not believe that rocks or large stones are driven by the junction of the tides. If they *are*, it is a serious objection, and most certainly I would not propose anything till I was master of this part of the subject. As to the expense, I suppose that it is not difficult to make a tolerable estimate. The tunnel would cost, at 30*l.* per foot, *running*, for 1000 feet, only 30,000*l.* Say 50,000*l.*:—it would bear but a small proportion to the expense of a bridge, which is stated at 250,000*l.* No scaffolding or centres will be wanting; and if it were determined that rocks are not carried by tides or storms through the channel, and if, as appears by Mr. Rennie's report, there is still water, at times, where the east and west tides meet, I do not see any great difficulty that could prevent this vast buoyant mass from floating gently to the place of its destination, nor in its being gradually sunk upon its bed in security. The length of the machine will [not] exceed three times the length of [a first-rate] man-of-war. Your very sincere and very old friend, RICHARD LOVELL EDGEWORTH."

"I admire your scheme," replied Mr. Watt, "of putting the tunnel together in a dry dock, and floating it into its place; but would not the construction of such a dock prove very expensive? and would not there be great risk of breaking some of the joints or pipes in floating it out, or in laying it upon its bed of sand? which latter would be with difficulty made of the same form as the tunnel.

"I believe no pipe or cylinder of 14 feet diameter has ever been cast of any considerable length, such as 9 feet, nor have I heard of any, even of 3 feet long, beyond 8 feet diameter. They must therefore, as I apprehend, be made in panels, 6 or 8 in the circumference, which infers many joints, flanches, and screws, besides fitting, which is very expensive. Should any part or joint fail after it is under water, repairs seem to me nearly impracticable, except by fishing up the whole. Cast-iron is not perfectly impervious to water when under considerable pressure. B., W., and Co. lined a coal-pit 20 fathoms deep with cast-iron cylinders, 1½ inch thick, in panels, I believe, and the water in many places sprang through the iron where it was apparently solid. Sea-water acts upon cast-iron without dissolving it, so as to change its nature, and to make it more resembling a brittle stone than iron. Bullets fished up out of the Spanish Armada ship, (sunk at the island of Mull,) at the beginning of the last century, were so soft as to be cut with a knife; and I have seen pumps at Wheal Virgin mine, in Cornwall, that by the vitriolic water had, in six years, been reduced to that state. In fresh water it lasts long.

"The expense of such a tunnel I cannot compute, though I believe there are ingenious founders in England who could, so far as the castings were concerned; but that, I should fear, would be the least part of it.

"The tunnel should be laid so low, that vessels, such as frequent that Strait, could pass over it at low water, or at least at any time of the tide that would serve them to come to it, otherwise some unlucky vessel might make a hole in it. I could not hope that the tunnel could be made so tight but that it would take in some water; therefore pipes should be laid within it, and an engine prepared to take out that water as it came in. There are other objections, some of which must have occurred to you, and I would trust to your ingenuity being able to obviate them. On the whole, my opinion remains unchanged, that if such a work is not impracticable, it would be extremely hazardous, and what I could not wish any friend of mine to engage it.

"I trust in your candour to pardon the freedom with which I criticise the scheme. I should consider myself unpardonable, holding the opinions I do, if I disguised them to *you*. Should you think them not valid, you must place them to the caution of age and my regard for you. I can have no other interest in dissuading you from it."

CHAPTER XXVIII.

MR. WATT IN OLD AGE—HIS PORTRAITURE BY SIR WALTER SCOTT—MADAME RUMFORD—THOMAS CAMPBELL—LOSS OF FRIENDS BY THEIR PREDECEASE—ROBISON, BLACK, WITHERING, DARWIN—PARTICULARS OF THE DEATH OF DR. BLACK—GREGORY WATT—ROBISON, BEDDOES, BOULTON, PATRICK WILSON, DE LUC—MR. WATT'S OWN LAST ILLNESS—AND DEATH—OFFER OF A BARONETCY—MONUMENTS TO HIS MEMORY—WESTMINSTER ABBEY—HANDSWORTH CHURCH—GLASGOW—GREENOCK—LORD JEFFREY'S CHARACTER OF HIM.

THE wonderful memory of Mr. Watt, at once comprehensive and tenacious;—his judgment, as clear as it was sound;—and the charms of his conversation, which captivated all listeners with its "Divine philosophy,"—seem never to have failed on this side of the grave:—a blessing seldom accorded to men of his advanced age, and not more rare than enviable. If his life opened amid clouds and storms, it was destined to close in sunlight and calm; in his peaceful retirement he had found a refuge, whence he could bid farewell alike to the illusions of Hope and the uncertainties of Fortune. He had gained for himself a most honourable place and name among the greatest and worthiest of mankind; he had "permanently elevated the strength and wealth of this great empire; and during the last long war, his inventions and their application were among the great means which enabled Britain to display power and resources so infinitely above what might have been expected from the numerical strength of her population." * Thus, in happy quiet, he reaped his large harvest of "laurels never sere."

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* Sir Humphry Davy, when President of the Royal Society; speech at the meeting at Freemason's Hall, 1824.

"His friends," says Lord Jeffrey, speaking of a visit which Mr. Watt paid to Scotland, when upwards of eighty, "in that part of the country, never saw him more full of intellectual vigour and colloquial animation, never more delightful or more instructive." * It was then, also, that Sir Walter Scott, meeting him, wrote:—"There were assembled about half a score of our Northern Lights. * * Amidst this company stood Mr. Watt, the man whose genius discovered the means of multiplying our national resources to a degree perhaps even beyond his own stupendous powers of calculation and combination; bringing the treasures of the abyss to the summit of the earth—giving the feeble arm of man the momentum of an Afrite—commanding manufactures to arise, as the rod of the prophet produced water in the desert—affording the means of dispensing with that time and tide which wait for no man—and of sailing without that wind which defied the commands and threats of Xerxes himself. This potent commander of the elements—this abridger of time and space—this magician, whose cloudy machinery has produced a change on the world, the effects of which, extraordinary as they are, are, perhaps, only now beginning to be felt—was not only the most profound man of science—the most successful combiner of powers, and calculator of numbers, as adapted to practical purposes—was not only one of the most generally well-informed, but one of the best and kindest of human beings.

"There he stood, surrounded by the little band I have mentioned of Northern literati, men not less tenacious, generally speaking, of their own fame and their own opinions, than the national regiments are supposed to be jealous of the high character which they have won upon service. Methinks I yet see and hear what I shall never see or hear again. In his eighty-second year, † the alert, kind, benevolent old man, had his attention alive to every one's question, his information at every one's command.

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* Character of Watt; see p. 406, *infrà*.

† Scott has said "eighty-fifth," but this we have ventured to correct.

"His talents and fancy overflowed on every subject. One gentleman was a deep philologist,—he talked with him on the origin of the alphabet as if he had been coeval with Cadmus; another a celebrated critic,—you would have said the old man had studied political economy and belles-lettres all his life;—of science it is unnecessary to speak, it was his own distinguished walk. And yet, Captain Clutterbuck, when he spoke with your countryman, Jedediah Cleishbotham, you would have sworn he had been coeval with Claver'se and Burley, with the persecutors and persecuted, and could number every shot the dragoons had fired at the fugitive Covenanters. In fact, we discovered that no novel of the least celebrity escaped his perusal, and that the gifted man of science was as much addicted to the productions of your native country, in other words, as shameless and obstinate a peruser of novels, as if he had been a very milliner's apprentice of eighteen." *

A passage of kindred interest, and, although less commonly adverted to, scarcely, we think, less striking to those who study *the manners of great minds*, occurs in Mr. Lockhart's Life of his illustrious connexion; where he says, "Scott never considered any amount of literary distinction as entitled to be spoken of in the same breath with mastery in the higher departments of practical life. * * To have done things worthy to be written was, in his eyes, a dignity to which no man made any approach who had only written things worthy to be read. He, on two occasions, which I can never forget, betrayed painful uneasiness when his works were alluded to as reflecting honour on the age that had produced Watt's improvement of the steam-engine, and the safety-lamp of Sir Humphry Davy. Such was his modest creed." †

We believe that Sir Walter could not possibly have felt a more profound reverence for the mighty labours of the great mechanical engineer, than Mr. Watt did for the magical powers of the glorious novelist and poet.

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* Introduction to 'The Monastery,' Abbotsford edition, vol. v., pp. 29, 30.

† Lockhart's 'Life of Scott,' chap. xxxv. p. 322, ed. 1842.

Compare the picture drawn by so perfect a master of his art as Sir Walter, with the following vigorous sketch, for which we are indebted to a less-practised feminine hand. If its features are scarcely so finished, its outlines seem scarcely less broad and forcible; and we believe the likeness which it expresses to be,—we cannot say more,—as striking and true. "He was one of the most complete specimens of the melancholic temperament. His head was generally bent forward or leaning on his hand in meditation; his shoulders stooping and his chest falling in, his limbs lank and unmuscular, and his complexion sallow. His intellectual development was magnificent; comparison and causality immense, with large ideality and constructiveness, individuality, and enormous concentrativeness and caution. Whilst Mr. Boulton's eye and countenance had something of radiance, Mr. Watt's were calm, as if patiently investigating, or quietly contemplating his object. His utterance was slow and unimpassioned, deep and low in tone, with a broad Scottish accent; his manners gentle, modest, and unassuming. In a company where he was not known, unless spoken to, he might have tranquilly passed the whole time in pursuing his own meditations. But this could not well happen; for in point of fact everybody practically knew the infinite variety of his talents and stores of knowledge. When he entered a room, men of letters, men of science, nay, military men, artists, ladies, even little children thronged round him. I remember a celebrated Swedish artist having been instructed by him that rats' whiskers make the most pliant painting brushes; ladies would appeal to him on the best means of devising grates, curing smoking chimneys, warming their houses, and obtaining fast colours. I can speak from experience of his teaching me how to make a dulcimer and improve a Jew's harp."* Mrs. SchimmelPenninck adds, "Mr. Watt was ever ready to give information, even to the most ignorant; and often do I remember his calling me to sit upon his knee, whilst he explained the different principles of the hurdy-gurdy or monochord, the harp, and the piano; or the construction of a simple whistle, or Pan's-pipe, or of an organ; but he never failed to tell me, that the hurdy-gurdy was the most venerable in point of antiquity, being no other than an adaptation of the celebrated monochord of Pythagoras."

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* 'Autobiography of Mary Anne SchimmelPenninck,' pp. 40, 41. 1858.

Among the many "celebrities" who, in the last years of its master, visited the retirement of Heathfield, (a small estate near Birmingham and Soho, which Mr. Watt had purchased in 1789, and on which he afterwards usually resided,) was the Countess Rumford; with whom, as Madame Lavoisier, Mr. Watt had made friendly acquaintance on his first visit to Paris. It is curious to observe how much scientific history of "'tis sixty years since," is epitomised in that lady's surrender, and subsequent transfer, of her affections; as well as in one, at least, of her intermediate refusals so to transfer them. In the dawn of her youth and beauty she was happily married to Lavoisier; and, in the noontide of his great reputation, made more than half the charm of his delightful home. But that tie having been too early severed by his dreadful death at the hands of the Revolutionists, she chose to marry, "en secondes noces," Thompson Count Rumford, and did *not* choose to marry Dr. Blagden. "Cavendish," says Lord Brougham, "having formed a high opinion of Dr. (afterwards Sir Charles) Blagden's capacity for science, settled a considerable annuity on him, upon condition that he should give up his profession and devote himself to philosophy; with the *former* portion of which condition the Doctor complied, devoting himself to the hopeless pursuit of a larger income in the person of Lavoisier's widow, who preferred marrying Count Rumford." *

"Watt himself," says Thomas Campbell, 'the Bard of Hope,' writing in February, 1819, "is now eighty-three; but so full of anecdote that I spent," (in his company at Heathfield,) "one of the most amusing days I have ever had with a man of science and a stranger to my own pursuits." †

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* 'Lives of Men of Science and Letters,' vol. i. p. 445, ed. 1845.

† Beattie's 'Life of Campbell,' vol. ii. p. 345.

And in the summer of the same year, Lord Brougham found Mr. Watt's instructive conversation, and his lively and even playful manner, unchanged.*

In 1794, Mr. Watt lost his old patron and associate Dr. Roebuck; in 1799, his dear friends Black and Withering; in 1802, Darwin "of the silver song," "almost his most ancient acquaintance and friend in England." The account which Dr. Robison sent him of the death of Dr. Black is striking and interesting:†—"Colonel Burnet has devolved on me the mournful task of informing you of the loss of your dear friend Dr. Black, who died last Friday. Knowing how severely you must feel this long expected stroke, I should hardly have accepted of the unpleasant office, were it not in my power to tell you that his end was such as his most affectionate friend could wish;—without a groan, and without warning. The servant had set down his little dinner before him, while he was busy with a tinman about a pan for warming his mess. Some time after, a gentleman called; the servant opened the door, and announced him, the Doctor sitting as usual," * * "in his chair, with his basin of milk on his knees, supported by one hand, the other leaning on the arm of the chair, and his chin resting on his breast, as he usually slept after dinner." ‡ * * "He made no answer, and John told the gentleman that his master was asleep, and desired him to call again; and then went down stairs. But, recollecting that the Doctor had scarcely had time to prepare and eat his little mess, and that he never had observed him fall asleep at dinner before, he went up again, opened the door, and went forward till he could see his master's face. He saw him with his eyes shut, and having his basin of milk, standing between his thighs, supported by his right hand. Thinking him asleep, and the milk in no danger of spilling, he went back again, and shut the door.

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* 'Lives of Men of Science and Letters of the Reign of George III.,' vol. i. p. 385.

† 11th December, 1799.

‡ 18th December, 1799.

"But as he was going down stairs, his heart misgave him, and he returned, and came forward, and called him by name pretty loud:—got no answer. He then took hold of his hand, and felt all cold:—in short, 'found,' as he said, 'that his poor master *had given over living.*' The basin was not fully supported by its position, and was really kept up by Dr. Black's hand.

"What an enviable close of life to every man! and to our dear friend it was inestimable. You know that his mind was elegance itself. He sometimes hinted his uneasiness at the thought of becoming silly, or slovenly, or squalid, and even of the last struggle of life; and could not bear the thought of any indecency of conduct or appearance. His wish was completely gratified, for life must have ceased without a pang. The servant told me that for an hour there was not any change observable on his countenance. Had skilful people been about him, that sweet countenance might have been preserved. When I saw him next morning, the lips had been allowed to contract.

"Dr. Black had been in remarkably good spirits ever since the beginning of autumn, and was as busy as a man hanging by his slender thread could be. He was scheming a new laboratory, to be built by subscription, of which he was to be the contriver and the architect; and he never was without some gentle occupation. Elegance and propriety modelled every thought, and his every sketch has a beauty which would be highly prized if found at Herculaneum. *Quando ullum inveniemus parem?*" * * "Any extravasation in the lungs must have provoked a cough, or a wry face, or caused some movement. Mr. George Bell, who saw him within five minutes after his death, (for the servant had seen him alive about that time before,) tells me that there was not the smallest appearance of his having had an uneasy sensation. He thinks that it was a paralytic affection of the diaphragm, of which the Doctor twice before complained to his father, saying that 'he had caught himself forgetting to breathe.' The heart, beating but feebly, ceased at the first omission of a stimulus from the pulmonic vein, (I think it is called.) I have heard that Colonel

Townshend died in one of his exhibitions of stopping his heart, and that it was without the least struggle. So departed our friend." * * "When I returned from London, at the account which I gave him of your triumph over Hornblower and Co. he was delighted, even to tears. He said, 'It is very foolish, but I can't help it, when I hear of anything good to Jamie Watt.'"

"Like you, I may say," replied Mr. Watt, "to him I owe in great measure my being what I am; he taught me to reason and experiment in natural philosophy, and was always a true friend and adviser, whose loss will always be lamented while I live. We may all pray that our latter end may be like his; he has, truly, gone to sleep in the arms of his Creator, and been spared all the regrets attendant on a more lingering exit. I could dwell longer on this subject, but regrets are unavailing, and only tend to enfeeble our own minds and make them less able to bear those ills we cannot avoid. Let us cherish the friends we have left, and do as much good as we can in our day!"

Dr. Black's fortune amounted to about 20,000*l.*, and in the disposal which he made of it among his very numerous relatives, he was true to the habits which chemistry had taught him, of minute and exact division; for, the better to enable himself to make the apportionment with due attention to the precise wants and just claims of each of his intended legatees, he divided the whole sum into 10,000 shares, and parcelled them out in what was said at the time to be a most unexceptionable manner.

In 1804, Mr. Watt's favourite son Gregory, the charms of whose presence and extraordinary talents were the ornament and pride of his race, languished and died of that insidious disease which so often destroys the most accomplished and the most lovely; and it was long ere the old man's feelings recovered their wonted tranquillity, which this severe blow had deeply disturbed. The loss of his early and ingenious companion Professor Robison in 1805; of Dr. Beddoes in 1808; of Mr. Boulton in 1809;*

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* In the notes which he added to the last edition of Professor Robison's Essay on the Steam-Engine, Watt, speaking of Mr. Boulton, expressed himself in

of his "dear friend" Dr. Patrick Wilson in 1811, and of De Luc in 1817, (at the great age of 93,)* as well as of many others who, though less known in the fields of science, were not less honoured by his cordial attachment, caused him emotions of sorrow to which he has repeatedly given utterance. "By one friend's withdrawing after another," he felt himself "in danger of standing alone among strangers, the sons of later times;" but such events were calls to him also to be ready, and such calls he habitually acknowledged and obeyed. "We cannot help feeling," he writes to Mr. Boulton,† "with deep regret, the circle of our old friends gradually diminishing, while our ability to increase it by new

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these terms:—"In 1774–5, I commenced a partnership with Mr. Boulton, which terminated with the exclusive privilege in the year 1800, when I retired from business; but our friendship continued undiminished to the close of his life. As a memorial due to that friendship, I avail myself of this, probably a last public opportunity, of stating, that to his friendly encouragement, to his partiality for scientific improvements, and his ready application of them to the processes of art: to his intimate knowledge of business and manufactures, and to his extended views and liberal spirit of enterprise, must in a great measure be ascribed whatever success may have attended my exertions."

The same lady who has so well sketched the mien and deportment of Mr. Watt, has left the following equally graphic description of Mr. Boulton:—"He was tall and of a noble appearance; his temperament was sanguine, with that slight mixture of the phlegmatic which imparts calmness and dignity; his manners were eminently open and cordial; he took the lead in conversations, and with a social heart had a *grandiose* manner like that arising from position, wealth, and habitual command. He went among his people like a monarch bestowing largess." Many anecdotes have been preserved of his highly upright and honourable feelings, as well as of his liberality and kindness to all who came within the circle of his influence; and it was truly said of "the princely Boulton," that "he dignified the name of a British manufacturer."—"His forehead was magnificent; the organs of comparison, constructiveness, and of individuality were immense." * * "Amongst those distinguished men, Mr. Boulton, by his noble manners, his fine countenance, (which much resembled that of Louis XIV.), and princely munificence, stood pre-eminently as the great Mæcenas."

* On what appears to have been Mr. Watt's last visit to him at Windsor, in July, 1811, he says he saw "poor Mr. De Luc, who cannot stir from his bed without help, but can sit and write, in which he occupies himself constantly. His memory and faculties seem entire. * * His present work is an account of his travels on the coasts of the Baltic."

† 23rd November, 1802.

ones is equally diminished; but perhaps it is a wise dispensation of Providence so to diminish our enjoyments in this world, that when our turn comes we may leave it without regret." So, eight years later, to another correspondent,* "I, in particular, have reason to thank God that he has preserved me so well as I am, to so late a period, while the greater part of my contemporaries, healthier and younger men, have passed 'the bourne from which no traveller returns.' It is, however, a painful contemplation to see so many who were dear to us pass away before us; and our consolation should be, that as Providence has pleased to prolong our life, we should render ourselves as useful to society as we can while we live." And again, when seventy-six years of age,† "On these subjects I can offer no other consolations than what are derived from religion: they have only gone before us a little while, in that path we all must tread, and we should be thankful they were spared so long to their friends and the world."

When, in the autumn of 1819, an illness of no great apparent severity,—but which also proved to be of no very long duration,—caused some little anxiety to Mr. Watt's friends, it was soon recognised by himself, with devout resignation, as the messenger sent to summon him away. In contemplation of the solemn event which he perceived was certainly approaching, he calmly conversed on that and other subjects with those around him; and expressed his gratitude to the Giver of All Good, who had so signally prospered the work of his hands, and blessed him with length of days, and riches, and honour.

On the 19th of August, at his own house at Heathfield, he tranquilly expired; and, amid the reverent sorrow of all classes of men, his remains were interred in the parish church of Handsworth, near those of his eminent and venerable associate, Mr. Boulton.

M. Arago, one of the most uncompromising, though, at the same time, the most pure-minded and amiable of republicans, has expressed, in his 'Eloge,' great and rather indignant surprise that "it was not even proposed to make Watt a Peer." The English Government was not altogether unmindful of the merits of Mr. Watt; and it was intimated to him, by a friendly message from Sir Joseph Banks, a few years before his death, that the highest honour usually conferred in England on men of literature and science,—(that of a Baronetcy),—was open to him, if he chose to express a wish to that effect. He felt flattered by the intimation, but on conversing with his son, it occurred to both, that there were circumstances and considerations which rendered it ineligible.

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* 12th July, 1810. † January, 1812.

Not long after Mr. Watt's death, it was understood that Lord Liverpool had publicly expressed regret, that a great opportunity of rewarding merit had been lost. That such were the sentiments of the King, (George IV.), and of the able men who then formed the ministry, became evident from the eagerness with which they entered into the proposal of erecting a public monument to the memory of Mr. Watt, when suggested by his friends, among whom Mr. Charles Hampden Turner took the lead. At the meeting at which provision was made for effecting that national object, the Prime Minister of the Crown occupied the chair, and announced that he was commanded by the King to say that he was most deeply sensible of the merits of Mr. Watt; that he was most anxious that there should be no subscription in testimony of such services in which his name should not appear; and that he was authorised to put down his Majesty's name for 500*l.*; while a Huskisson, a Peel, an Aberdeen, and a Brougham, vied with a Davy, a Mackintosh, a Wilberforce, and a Wedgwood, in expressing their sense of the value of the magnificent inventions with which the name of Watt was associated. "A meeting more distinguished by rank, station, and talent,"—as it was truly remarked at the time,—"was never assembled to do honour to genius, and to modest and retiring worth; and a more spontaneous, noble, and discriminating testimony was never borne to the virtues, talents, and public services of any individual, in any age or country." To be so honoured by those most full of honour, and praised by the most praiseworthy, seems to leave nothing more to be desired in the way of posthumous fame, of private respect, or national esteem.

The tribute which a grateful nation has since paid to his memory is thus testified not only by those monuments which in other places throughout the kingdom his countrymen have set up, but also by the colossal statue, from the chisel of Chantrey, erected in Westminster Abbey. The inscription is as follows:—

NOT TO PERPETUATE A NAME
WHICH MUST ENDURE WHILE THE PEACEFUL ARTS FLOURISH
BUT TO SHEW
THAT MANKIND HAVE LEARNT TO HONOUR THOSE
WHO BEST DESERVE THEIR GRATITUDE
THE KING
HIS MINISTERS AND MANY OF THE NOBLES
AND COMMONERS OF THE REALM
RAISED THIS MONUMENT TO
JAMES WATT
WHO DIRECTING THE FORCE OF AN ORIGINAL GENIUS
EARLY EXERCISED IN PHILOSOPHIC RESEARCH
TO THE IMPROVEMENT OF
THE STEAM ENGINE
ENLARGED THE RESOURCES OF HIS COUNTRY
INCREASED THE POWER OF MAN
AND ROSE TO AN EMINENT PLACE
AMONG THE MOST ILLUSTRIOUS FOLLOWERS OF SCIENCE
AND THE REAL BENEFACTORS OF THE WORLD
BORN AT GREENOCK MDCCXXXVI
DIED AT HEATHFIELD IN STAFFORDSHIRE MDCCCXIX.

Lord Brougham's composition has, indeed, attained the distinction of being declared "beyond all comparison the finest lapidary inscription in the English language," and is said by the same authority to have, "among its other signal merits, one which appertains rather to its subject than its author, that, lofty as is the eulogy, every word of it is true."*

The filial piety of the late Mr. Watt of Aston Hall has liberally and judiciously multiplied those noble statues of his father, which have been justly regarded as Chantrey's greatest works. Thus the Town of Greenock, the University of Glasgow, and the Church of Handsworth, each possesses one of those exquisite pieces of memorial sculpture, truthfully portraying to distant ages the mild, thoughtful, and venerable features of the patriarchal sage, and with silent but impressive eloquence commemorating the birth, the life, the inventions, and the death of James Watt.

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* 'Quarterly Review,' vol. CIV. p. 451. 1858.

"This name," wrote Lord Jeffrey, on receiving the first intelligence of the death of his venerated friend,—and the portraiture he then rapidly drew will always remain unsurpassed in fidelity and power,—"fortunately needs no commemoration of ours; for he that bore it survived to see it crowned with undisputed and unenvied honours; and many generations will probably pass away before it shall have gathered 'all its fame.' We have said that Mr. Watt was the great *improver* of the steam-engine; but, in truth, as to all that is admirable in its structure, or vast in its utility, he should rather be described as its *inventor*. It was by his inventions that its action was so regulated, as to make it capable of being applied to the finest and most delicate manufactures, and its power so increased, as to set weight and solidity at defiance. By his admirable contrivance, it has become a thing stupendous alike for its force and its flexibility,—for the prodigious power which it can exert, and the ease, and precision, and ductility, with which it can be varied, distributed, and applied. The trunk of an elephant, that can pick up a pin or rend an oak, is as nothing to it. It can engrave a seal, and crush masses of obdurate metal before it,—draw out, without breaking, a thread as fine as a gossamer, and lift a ship of war like a bauble in the air. It can embroider muslin and forge anchors,—cut steel into ribbons, and impel loaded vessels against the fury of the winds and waves.

"It would be difficult to estimate the value of the benefits which these inventions have conferred upon this country. There is no branch of industry that has not been indebted to them;

and, in all the most material, they have not only widened most magnificently the field of its exertions, but multiplied a thousand-fold the amount of its productions. It is our improved steam-engine that has fought the battles of Europe, and exalted and sustained, through the late tremendous contest, the political greatness of our land. It is the same great power which now enables us to pay the interest of our debt, and to maintain the arduous struggle in which we are still engaged, [1819], with the skill and capital of countries less oppressed with taxation. But these are poor and narrow views of its importance. It has increased indefinitely the mass of human comforts and enjoyments, and rendered cheap and accessible, all over the world, the materials of wealth and prosperity. It has armed the feeble hand of man, in short, with a power to which no limits can be assigned; completed the dominion of mind over the most refractory qualities of matter; and laid a sure foundation for all those future miracles of mechanic power which are to aid and reward the labours of after generations. It is to the genius of one man, too, that all this is mainly owing; and certainly no man ever bestowed such a gift on his kind. The blessing is not only universal, but unbounded; and the fabled inventors of the plough and the loom, who were deified by the erring gratitude of their rude contemporaries, conferred less important benefits on mankind than the inventor of our present steam-engine.

"This will be the fame of Watt with future generations; and it is sufficient for his race and his country. But to those to whom he more immediately belonged, who lived in his society and enjoyed his conversation, it is not, perhaps, the character in which he will be most frequently recalled,—most deeply lamented,—or even most highly admired. Independently of his great attainments in mechanics, Mr. Watt was an extraordinary, and in many respects a wonderful man. Perhaps no individual in his age possessed so much and such varied and exact information,—had read so much, or remembered what he had read so accurately and well. He had infinite quickness of apprehension, a prodigious memory, and a certain rectifying and methodising power of understanding, which extracted something precious out of all that was presented to it. His stores of miscellaneous knowledge were immense,—and yet less astonishing than the command he had at all times over them. It seemed as if every subject that was casually started in conversation with him, had been that which he had been last occupied in studying and exhausting;—such was the copiousness, the precision, and the admirable clearness of the information which he poured out upon it without effort or hesitation. Nor was this promptitude and compass of knowledge confined in any degree to the studies connected with his ordinary pursuits. That he should have been minutely and extensively skilled in chemistry and the arts, and in most of the branches of physical science, might perhaps have been conjectured; but it could not have been inferred from his usual occupations, and probably is not generally known, that he was curiously learned in many branches of antiquity, metaphysics, medicine, and etymology, and perfectly at home in all the details of architecture, music, and law. He was well acquainted, too, with most of the modern languages,—and familiar with their most recent literature. Nor was it at all extraordinary to hear the great mechanician and engineer detailing and expounding, for hours together, the metaphysical theories of the German logicians, or criticising the measures or the matter of the German poetry.

"His astonishing memory was aided, no doubt, in a great measure, by a still higher and rarer faculty,—by his power of digesting and arranging in its proper place all the information he received, and of casting aside and rejecting, as it were instinctively, whatever was worthless or immaterial. Every conception that was suggested to his mind seemed instantly to take its place among its other rich furniture, and to be condensed into the smallest and most convenient form. He never appeared, therefore, to be at all encumbered or perplexed with the *verbiage* of the dull books he perused, or the idle talk to which he listened; but to have at once extracted, by a kind of intellectual alchemy, all that was worthy of attention, and to have reduced it, for his own use, to its true value and to its simplest form. And thus it often happened, that a great deal more was learned from his brief and vigorous account of the theories and arguments of tedious writers, than an ordinary student could ever have derived from the most painful study of the originals,—and that errors and absurdities became manifest from the mere clearness and plainness of his statement of them, which might have deluded and perplexed most of his hearers without that invaluable assistance.

"It is needless to say, that, with those vast resources, his conversation was at all times rich and instructive in no ordinary degree: but it was, if possible, still more pleasing than wise, and had all the charms of familiarity, with all the substantial treasures of knowledge. No man could be more social in his spirit, less assuming or fastidious in his manners, or more kind and indulgent towards all who approached him. He rather liked to talk,—at least in his latter years; but though he took a considerable share of the conversation, he rarely suggested the topics on which it was to turn, but readily and quietly took up whatever was presented by those around him, and astonished the idle and barren propounders of an ordinary theme, by the treasures which he drew from the mine they had unconsciously opened. He generally seemed, indeed, to have no choice or predilection for one subject of discourse rather than another; but allowed his mind, like a great cyclopædia, to be opened at any letter his associates might choose to turn up, and only endeavour to select, from his inexhaustible stores, what might be best adapted to the taste of his present hearers. As to their capacity he gave himself no trouble; and, indeed, such was his singular talent for making all things plain, clear, and intelligible, that scarcely any one could be aware of such a deficiency in his presence. His talk, too, though overflowing with information, had no resemblance to lecturing or solemn discoursing, but, on the contrary, was full of colloquial spirit and pleasantry. He had a certain quiet and grave humour, which ran through most of his conversation, and a vein of temperate jocularity, which gave infinite zest and effect to the condensed and inexhaustible information which formed its main staple and characteristic. There was a little air of affected testiness, and a tone of pretended rebuke and contradiction, with which he used to address his younger friends, that was always felt by them as an endearing mark of his kindness and familiarity,—and prized accordingly, far beyond all the solemn compliments that ever proceeded from the lips of authority. His voice was deep and powerful,—though he commonly spoke in a low and somewhat monotonous tone, which harmonized admirably with the weight and brevity of his observations, and set off to the greatest advantage the pleasant anecdotes, which he delivered with the same grave brow, and the same calm smile playing soberly on his lips. There was nothing of effort indeed, or impatience, any more than of pride or levity, in his demeanour; and there was a finer expression of reposing strength, and mild self-possession in his manner, than we ever recollect to have met with in any other person. He had in his character the utmost abhorrence for all sorts of forwardness, parade, and pretensions; and, indeed, never failed to put all such impostures out of countenance, by the manly plainness and honest intrepidity of his language and deportment.

"In his temper and dispositions he was not only kind and affectionate, but generous, and considerate of the feelings of all around him; and gave the most liberal assistance and encouragement to all young persons who showed any indications of talent, or applied to him for patronage or advice. His health, which was delicate from his youth upwards, seemed to become firmer as he advanced in years; and he preserved, up almost to the last moment of his existence, not only the full command of his extraordinary intellect, but all the alacrity of spirit, and the social gaiety, which had illumined his happiest days. His friends in this part of the country never saw him more full of intellectual vigour and colloquial animation,—never more delightful or more instructive,—than in his last visit to Scotland in autumn, 1817.

Indeed, it was after that time that he applied himself, with all the ardour of early life, to the invention of a machine for mechanically copying all sorts of sculpture and statuary;—and distributed among his friends some of its earliest performances, as the productions of a young artist just entering on his eighty-third year.

"This happy and useful life came, at last, to a gentle close. He had suffered some inconvenience through the summer; but was not seriously indisposed till within a few weeks from his death. He then became perfectly aware of the event which was approaching; and, with his usual tranquillity and benevolence of nature, seemed only anxious to point out to the friends around him, the many sources of consolation which were afforded by the circumstances under which it was about to take place. He expressed his sincere gratitude to Providence for the length of days with which he had been blessed, and his exemption from most of the infirmities of age; as well as for the calm and cheerful evening of life that he had been permitted to enjoy, after the honourable labours of the day had been concluded. And thus, full of years and honours, in all calmness and tranquillity, he yielded up his soul, without pang or struggle,—and passed from the bosom of his family to that of his God.

"He was twice married, but has left no issue but one son, long associated with him in his business and studies, and two grandchildren by a daughter who predeceased him. He was a Fellow of the Royal Societies both of London and Edinburgh, and one of the few Englishmen who were elected members of the National Institute of France. All men of learning and science were his cordial friends; and such was the influence of his mild character and perfect fairness and liberality, even upon the pretenders to these accomplishments, that he lived to disarm even envy itself, and died, we verily believe, without a single enemy."

Mr. Watt became a Fellow of the Royal Society of Edinburgh in 1784; of the Royal Society of London in 1785; a

Member of the Batavian Society in 1787; and a Correspondent of the Institute of France in 1808. By a spontaneous and unanimous vote, the Senate of the University of Glasgow conferred on him, in 1806, the honorary degree of Doctor of Laws. In 1814, the Academy of Sciences of the Institute paid him the highest honour which it could bestow; it nominated him one of its Eight Foreign Associates.

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